NATURAL HAZARDS
A PUBLIC POLICY ASSESSMENT

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16. Abstract (Limit: 200 words)
This study was concerned with the: 1) identification and description of the characteristics, geographic distribution, and potential effects of nine hazardous natural events within the United States; 2) assessment of the vulnerability of several classes of buildings, and their occupants, to each hazard; 3) identification and measurement of the major primary, secondary, and higher order effects expected to be associated with the exposure, by major geographic area, of buildings and their occupants to these hazardous natural events; 4) identification and explication of the major candidate public problems which are associated with these effects; 5) identification of the costs and characteristics of the major types of technologies appropriate for mitigating the effects induced by exposure of buildings and their occupants to each of the nine natural hazards; 6) identification and description of the major types of public policies which may induce the application of hazard-mitigating technologies; 7) estimation of the economic costs and other effects associated with the use of selected technologies to mitigate the effects of these hazards; 8) identification of the major effects and candidate public problems which might be generated by the use of selected technologies in mitigating the effects; 9) identification and evaluation of the major problem-solving strategies and public policies which are relevant to the problems identified.

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FOREWORD

Throughout history, individuals and governments have sought means for limiting the adverse impacts associated with the exposure of people and property to the hazards of the natural environment. In the United States, the hazards of major concern have included: riverine flood; coastal storm surge; tsunami; earthquake; expansive soils; landslide; hurricane wind; tornado; and severe wind.

In attempts to mitigate the effects of exposures to these hazards, rivers have been dammed, deepened and diked. Coastlines have been equipped with sea walls; storm cellars have been dug in backyards; buildings have been elevated above the level of expected flood heights; and a variety of means have been employed to strengthen structures and thereby reduce their vulnerability to the forces exerted by winds, land movement, and other natural hazards. Numerous types of building strengthening, area protection, site development, and other technologies are available for use by those who wish to reduce the risks associated with exposure to natural hazards, and the mandatory application of these technologies can be forced through adoption of a wide variety of federal, state, and local public policies. The risk of loss may be spread through use of insurance schemes, and the impact of catastrophic hazardous occurrences on exposed populations may be reduced through disaster relief and recovering measures financed by non-impacted parties.

However, every public and private response which can be made to the risks presented by natural hazard exposures imposes costs on someone, somewhere, at some time. In some cases, the costs of such ventures may exceed the value of the risk reduction produced by the purchased mitigation; in still other cases, the use of the mitigation may engender a false sense of public security and lure additional numbers of people into contact with hazardous areas and thereby increase the total losses associated with such exposures. What to do about the continuing exposure of people and property to natural hazards is, therefore, both a question of considerable complexity as well as one of increasing importance to public policy makers at federal, state, and local levels. Should building code requirements be strengthened? Should governmentally enforced restrictions be imposed on the use of such hazardous areas as floodplains, earthquake-prone sites, and steep hillsides subject to land slippage? What public problems are posed by the voluntary and involuntary exposure of people and property to natural hazards, and what problems might be produced by public effort to control such exposures?

It is to these and other important questions that this report is addressed. Funded as a technology assessment by the National Science Foundation under the terms of Grants ERS-75-09998 and AEN-74-23992, and purchase order 78-SP-0620, the purpose of the study which has culminated in this report was not to tell policy-makers what public problems are presented by natural hazard exposures in the United States, nor to tell policy-makers what solutions should be applied to such problems.

Instead, its purposes are to present data and factual conclusions which may aid policy-makers in performing this task; to identify the various stakeholder groups whose interests are bound up in hazard exposure and hazard mitigation situations; to identify candidate lists of possible public problems; to identify the range of technologic and policy options which may be appropriate to solving each listed candidate problem; and to assess the more important costs and benefits associated with each.

Conducted by an interdisciplinary team of investigators, the study utilized risk analysis techniques which resulted in: (1) the generation of annual expected natural hazard loss estimates for 1970 and 2000; (2) identification of specific strategies and technologies theoretically capable of reducing such losses; (3) identification of the amortized annual costs associated with use of selected mitigation strategies; (4) identification of the candidate public problems and stakeholder groups associated with natural hazard exposures and alternative technology-forcing policy options; (5) identification and critical evaluation of past and current public policies, institutional arrangements, and administrative practices aimed at mitigation of natural hazards losses; (6) identification and assessment of the contemporary social, technical, administrative, political, legal, and economic constraints on natural hazards policy making operations; (7) the development and assessment of policy options appropriate for coping with hazard-related public problems between 1970 and 2000.

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Chapter One

PURPOSES AND APPROACH OF STUDY

Introduction and Summary

This report is the product of a problem-oriented technology assessment (TA) funded by the National Science Foundation under NSF Grant No. ERP 75-09998. The assessment was aimed at identification of the potential impacts, problems, mitigation technologies, and policy alternatives associated with the exposure of people and property to nine natural hazards in the United States. One of the few primarily problem-oriented TAs funded by the National Science Foundation [Armstrong and Harmon, 1977], this study utilized probabilistic risk analysis techniques to develop average annual (annualized) estimates of selected natural hazard losses for individual counties, states, and the nation for the years 1970 and 2000. It also employed a model of the public policy and public problem-causing system which permitted the project team to develop distinctions between natural hazard "impacts" and "public problems," to identify the "stakeholders" whose interests are associated with natural hazard exposure and hazard-mitigating actions, and to identify the linkages between technology-applying policy alternatives and the stakeholders, problems, and impacts to which such policies are addressed, related, or causally linked.

Purposes, Characteristics and Approaches of Technology Assessment Projects

Closely linked to the public policy process, technology assessment projects seek to support rational decision making by parties who are responsible for determining when, where, how, and to what extent a specific technology should be applied. As observed by the Office of Technology Assessment [1975]:

> The objective of each assessment is to provide an early appraisal of the probable impacts and uncertainties of technology programs, so that both beneficial and adverse factors can be identified and considered in the legislative planning process. Both near-term and longer-term effects, whether intended or unintended, are examined, as are the diverse interests and viewpoints of the many different parties foreseeably to be affected by the technology.

> Technology assessment...is a process designed to ask the right questions and to seek answers based - as much as possible - on hard, factual information which can be obtained through disciplined analysis. Where important data are unavailable, the need for additional research can be spotlighted. Technology assessment is an aid to, not a substitute for, the judgments which must be reached by officials in policy-making positions.

Joseph Coates [1976] has suggested that

> ...technology assessment is the name for a class of policy studies which attempt to look at the widest possible scope of impacts in the society of the introduction of a new technology or the extension of the established technology in new and different ways. Its goal is to inform the policy process by putting before the decision maker an analyzed set of options, alternatives and consequences...(it) is extremely wide-sweeping in scope; it is not the decision process itself but only one input into that process.

Similarly, D.E. Kash [1977] has observed that "technology assessments are a class of policy studies which assume that technologies cause or have significant influence on social change." Kash suggests that four important questions are asked by assessors of technology: (1) What are the consequences resulting from the use of the technology, as distinguished from the impacts that are used to justify its development? (2) Do the stakeholders see themselves as affected beneficially or adversely, and how intensely? (3) What can be done to enhance beneficial impacts? (4) What are the technological-social options that can modify impacts in the direction desired by policy makers and affected parties?

Armstrong and Harmon [1977] reviewed numerous definitions of the term and concluded that all of the examined definitions arise from two basic assumptions: (1) that the implementation of a new technology or the expansion of an old one is (or should be) a conscious societal choice; and (2) that it is not technology itself which is inherently harmful to society, but rather the consequences of the decisions concerning the ways in which the technology will be applied and managed.

Types of Technology Assessments

Based on their examination of 24 technology assessments funded by the National Science Foundation, Armstrong & Harmon concluded that these assessments could be classified into two major types: the problem-oriented and the technology-oriented. These authors agreed with a report by the National Academy of Engineering which suggested that a problem-oriented technology assessment is one which focuses on one or more central problems and then considers alternative candidate solutions to each problem. [U.S. Congress, Joint Office of Technology Assessment, 1977].

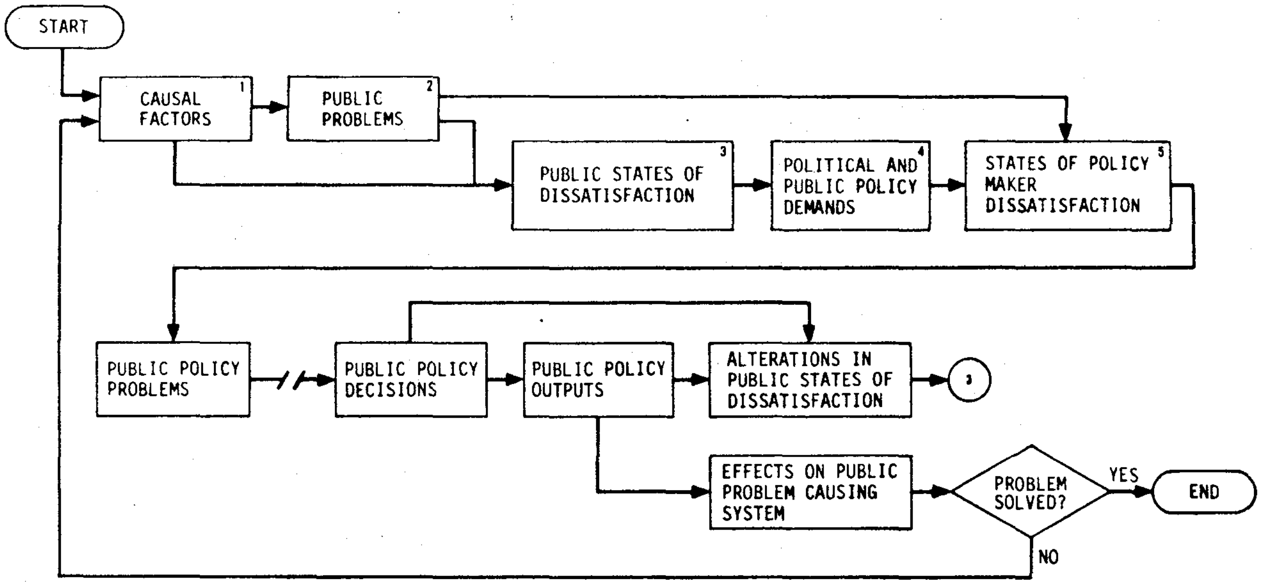
Candidate solutions typically contain a mix of physical and management technologies. Armstrong and Harmon suggest that problem-oriented technology assessments "are generally more complex than technology-oriented ones because detailed information on several different technologies must be assimilated and compared." In contrast to the problem-oriented assessment, a technology-oriented assessment projects into the future a single technology along alternative paths. Often, Armstrong and Harmon observe, "technology-oriented technology assessments serve as inputs into larger studies or assessments and by so doing, serve to illuminate one aspect of the spectrum of candidate solutions."
[Armstrong and Harmon, 1977].

These authors further suggest that, whether the focus of an assessment is on problems or technologies, the consideration of technologies tends to focus on one of three classes: a physical technology, a management technology, or a combination of the two. The technologic focus may be further characterized by examination of an existing or emerging technology.

Whatever the focus of a technology assessment, it seems clear that the primary purpose behind its conduct is to provide informed, comprehensive inputs to the public policy system, while making explicit the value orientations within which decisions are to be made.

Characteristics of the Public Policy System

From the perspective of Anderson [1975], Jones [1977], and others, the process through which public policies are framed, adopted, implemented, and amended is characterized by several critical events, all of which are depicted in Figure 1-1.



Suggested by: (1) James E. Anderson, Public Policy Making. New York: Praegon Publishers (1975); (2) Charles O. Jones, An Introduction to The Study of Public Policy (2nd edition, 1977)

Figure 1-1. Linkages Between Public Problems, Public Policies and Alternatives in Public Problem-causing Systems

Within the limits of the Anderson-Jones perspective, the public policy process begins when some state of affairs is intrinsically or instrumentally disvalued by an element of society and is perceived by it to qualify as a "public problem." The perceived existence of this state of affairs may subsequently generate a public state of dissatisfaction and lead to issuance of demands on the public policy system. Under appropriate circumstances these demands may result in policy-maker dissatisfaction and the subsequent inclusion of policy-making requests on the public policy agenda. At this stage in the process, a "public policy problem" may be said to have been identified. Thereafter, the inclusion of an item on the public policy agenda leads to the making of one or more public policy decisions, to the output of governmentally-generated services or products, and to the generation of "policy output effects." If decisions have been appropriately framed and decision-implementing activities have been appropriately conducted, the supposition is that these policy output effects will include a resolution or amelioration of the "public problem" which activated the entire sequence of events; and that no new "public problems" will result from the decision-making process, the decisions themselves, or the decision-implementing activities which were a part of the policy process.

Public Problems and Policy Analysis

Within the context of the above perspective, the rational capacity of the public policy system may be increased if that system is provided with two types of inputs: public problem analyses and public policy analyses. Problem analyses identify: (1) problem states of affairs; (2) networks of causes and effects to which these states are linked; (3) underlying values associated with the states; and (4) value-holders and problem-experiencing populations and areas. Policy analyses identify: (1) alternative problem-solving strategies and policy choices; (2) criteria for the selection of policy alternatives; (3) decision-influencing constraints; and (4) the payoffs, outcomes, and side effects which may be expected from each policy alternative.

Since most technology assessments generally have failed to recognize the significance of problem analysis, it is important to note that problem analyses may be viewed as constituting the interface between technology assessments, public policy analyses, and the acts of public decision-making which are the raison d'être for the entire set of activities.

Regardless of their foci, all technology assessments must identify "public problems." On the one hand, a problem-focused TA must identify the "public problems" which justify the conduct of the TA. On the other hand, a technology-oriented TA must identify the "public problems" which either justify the application of the technology or are suspected to result from the use of the technology.

Risk Analysis

Risk analysis is a specialized set of operations which is subsumed within a problem analysis. Risk is a function of two major factors: (a) the probability that an event will occur and (b) the consequences of the event. Hence, risk analysis is aimed at identifying: (a) the probability that particular events at certain intensities will occur over some specified time frame, (b) the area or population which will be exposed to the events (e.g., the polulation at risk), (c) the vulnerability of the area or exposed polulation to effects associated with the events, and (d) the consequences to the population at risk of exposure to the expected series and intensities of the events over specified time frame.

The outputs of a risk analysis may form probabilistically-derived, annualized estimates of the consequences to the population-at-risk which will arise from exposure to the hazard [Rowe, 1977 & Lowrance, 1976].

Characteristics of Public Problems

The task of identifying a public problem is different from the task of identifying an "impact." As the term is used in most TAs, the latter is nothing more than some empirically-verifiable consequence of some defined cause. An impact is inherently neither good nor bad, but is simply a state of affairs which has been observed to have been produced by some set of causes. In contrast, following the lead of Bartee [1972] and Ong and Atkisson [1976], we define problems as situations in which a person disvalues a gap which is perceived to exist between some desired and some perceived state of affairs.

A model depicting this perspective and linking it to the Jones-Anderson model of the public policy process, is presented in Figure 1-2.

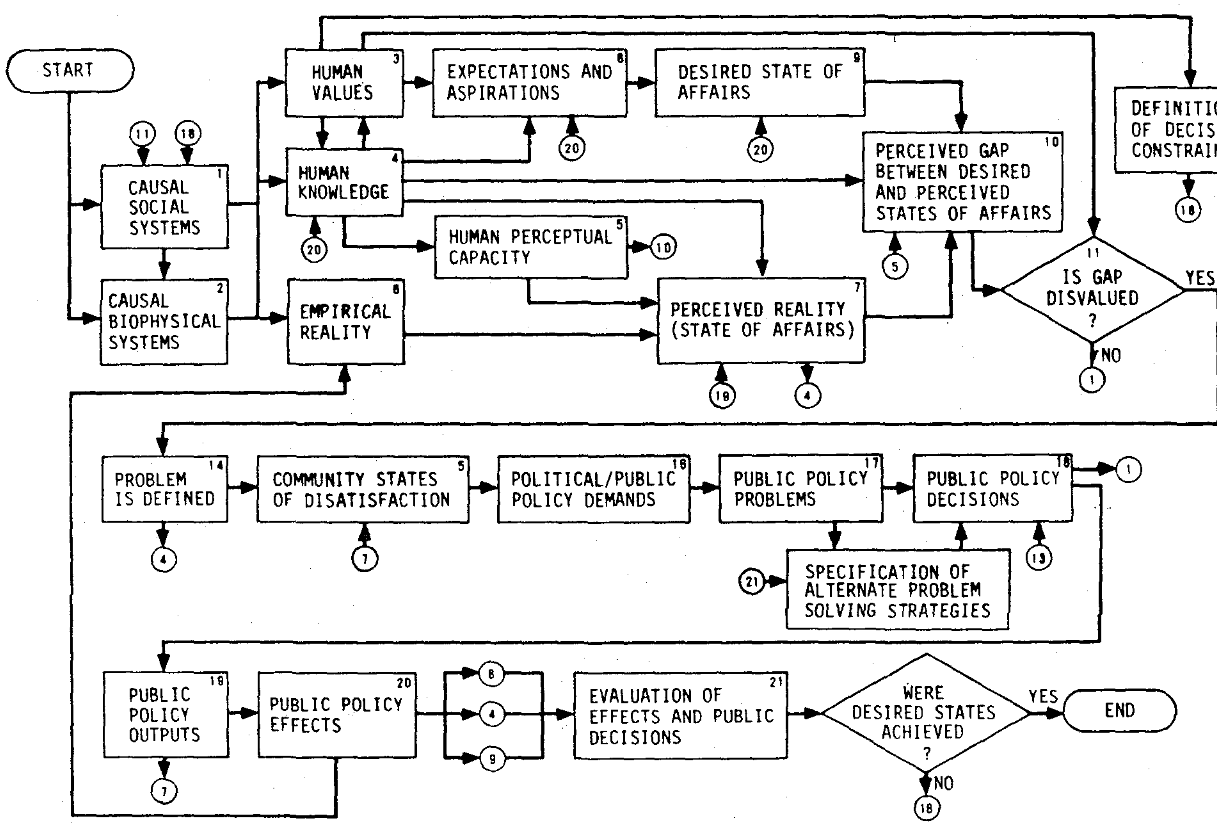


Figure 1-2. The Public Problem-defining and Problem-solving Process

As shown in Figure 1-2, all problems may be said to be the product of four factors: human perceptions of empirical reality, human desires and expectations for the future, values which justify and define the desired future, and the human perception of gaps between the desired future and the present. Whenever a gap has been perceived to exist between a desired and a perceived state of affairs, and whenever that gap has been disvalued by the observer, then a problem may be said to be present. Thus, problems are as much a product of human values and of human perceptions as they are of the empirical reality to which they are presumed to relate.

Of course, not all "problems" may appropriately be defined as "public problems." Hemphill [1967], for example, has argued that all problems may be divided into three main classes: (1) individual problems; (2) social problems; (3) mutual problems. He defines the class of individual problems as those states in which the individual may reach some personal goal (viz., close a gap between some personally desired and personally-perceived state of affairs) without involving another person in the process. On the other hand, Hemphill defines a social problem as one in which the achievement of some state of affairs desired by one person requires that the goal-seeking person involve another individual in the goal accomplishing action. The common element in both individual and social problems is that the focal goal is held by only a single person. In contrast, a mutual problem, says Hemphill, is:

> ...a state of affairs existing within a situation of which two or more individuals are a part, each of whom perceives it as dissatisfying, and which requires some behavior on the part of the other if either (any) is to be satisfied...
>
> A mutual problem is distinguished from all other social problems in that (all) individuals are dissatisfied with at least some part of the state of affairs, and both (all) must become involved if satisfaction is to be achieved, i.e., if the problem is to be solved...
>
> It is not necessary that the individuals involved be dissatisfied about the same thing. They need not share a common goal (although they may -- in which case it can be said that they have a common problem). In fact, individuals are frequently dissatisfied with different parts of the same state of affairs or with the same parts but in different ways.

However appealing the Hemphill perspective may be, considerable difficulty is encountered when one tries to specify those criteria which may be utilized by an intendedly value-neutral observer to distinguish "public" from all other types of problems. The difficulty arises, in part, because of the mixed normative and empirical factors associated with such an effort.

Empirically, it seems clear that a "public problem" is whatever a properly-sanctioned social entity defines such a state as being. In democratic societies, at least, those states of affairs which are widely defined as being public problems are the product of whatever criteria the electorate or their legislative bodies utilize to distinguish public from private problems. On the other hand, a variety of normative criteria have been suggested by various philosophers, analysts and participants in political processes as being appropriate for resolving such questions. For example, John Dewey has suggested criteria which closely resemble those utilized by modern economists to identify "externalities." Dewey [1927] observed that:

> some... human acts have consequences upon others, that some of these consequences are perceived, and that their perceptions lead to subsequent efforts to control action, so as to secure some consequences and to avoid others.... Consequences are of two kinds: those which affect the persons directly engaged in the transaction, and those which affect others beyond those immediately concerned. In this distinction, we find the germ of the distinction between the private and the public.... the public consists of all those who are affected by the indirect consequences of the transaction to an extent that it is deemed necessary to have those consequences systematically cared for.

Since the actors in a democratic problem-defining process are free to utilize Dewey's criterion, or any other of their choice, some may deem it most appropriate simply to define public problems as states of affairs which exhibit the following attributes:

(a) they are deemed dissatisfying by one or more individuals, but;

(b) the solution requires action by parties other than the individuals experiencing the dissatisfaction; and

(c) governmental action is necessary to stimulate action by private parties or to assist the dissatisfied (problem-impacted) and problem-causing parties in their cooperative problem-solving venture.

Comprehensive and Value-neutral Policy Assisting Study Operations

In terms of the definitions and perspectives offered above, an ideal expression of the operations and outputs associated with problem-focused, comprehensive, and value-neutral policy-assisting analyses is presented in Figure 1-3.

Analyses of this type are concerned with the identification of the specific events which characterize given situations; with the identification of those situations which qualify as candidate public problems; with explication of the causal systems which give rise to the focal problems; and with specification of alternative strategies for resolving the problems.

These analyses also present information which identifies the constraints to be met by decision makers in selecting strategies for problem solutions. The mix of most relevant constraints are those suggested by the acronym, STAPLE: Social, Technical, Administrative/Institutional, Political, Legal, and Economic constraints. From our perspective, these constraints arise from the value commitments, goals and aspirations of societal groups, and require their reaction to the "higher-order" and socially-diffused effects of alternate strategies for problem-solution.

Definition of Critical Terms

As noted above, this report is the product of a technology assessment which was primarily problem-oriented. Its focus is on identification and explication of the impacts associated with the occurrence of hazardous natural events, on identification of the "public problems" associated with those impacts, on identification of the alternative physical and management technologies appropriate for eliminating or reducing those problems, and on identification and analysis of the impacts and problems associated with the use of the physical and management technologies themselves.

Accordingly, the report makes continuing use of the terms which are defined Figure 1-4.

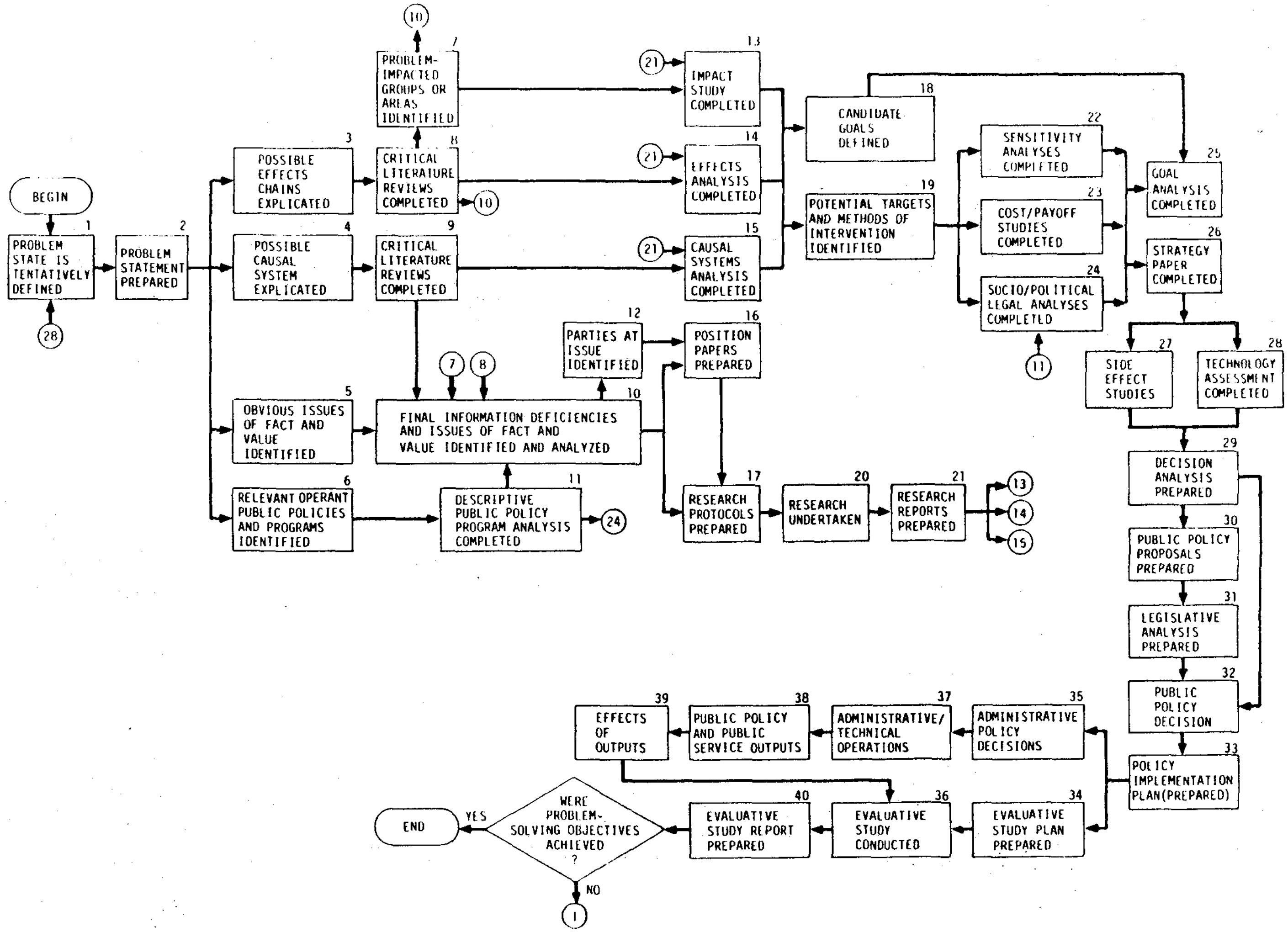


Figure 1-3. Comprehensive, Value-Neutral, Policy-Assisting Study System

TERM	DEFINITION
1. EMPIRICAL REALITY	The correct or accurate images of the "real world" which may be developed through intendedly rational methods of observation, data collection, and data analysis.
2. PERCEIVED REALITY	The images of the "real world" which are held by one or more human beings without regard to the means through which those images were formed. The images may or may not be "correct" reflections of reality.
3. PROBLEMS	A situation in which one or more individuals disvalue a gap which is perceived to exist between a desired and a perceived state of affairs. An individual problem meets these criteria, but the disvaluing is by an individual who has the capacity to correct the situation. Similarly, a social problem also meets these criteria, but correction of the problem requires action by at least one other than the person experiencing the problem. On the other hand, a mutual problem is one in which two or more parties disvalue the existance of some situation, although perhaps for different reasons, and neither is able to correct the situation through independent action.
4. INTRINSICALLY-DISVALUED STATES OF AFFAIRS	These states or problems, are disvalued in and of themselves because of their incongruence with the value orientation and/or aspirations/expections of the disvaluing agent.
5. INSTRUMENTALLY-DISVALUED STATES OF AFFAIRS	These states are disvalued, not in and of themselves, but because they lead to, or are perceived to lead to, still other states of affairs which are intrinsically disvalued.
6. PROBLEM-CAUSING SYSTEM	A problem-causing system consists of the network of causal factors which leads to, or is suspected of leading to the occurrence of some state of affairs, together with the value premises and perceptions which lead to the identification of disvaluing of that state. The network of causal factors leading to the focal state may be viewed as consisting of two sub-systems: (a) the causal biophysical sub-system; and (b) the causal socio-cultural sub-system. The latter consists of the individual, group and social decisions and/or decision premises which are, in any situation, observed to be responsible for the occurrence of a biophysical causal factor.
7. PROBLEM-SOLVING STRATEGY	A set of operational routines which have been selected to guide an intervention into a problem-causing system. Such an intervention is focused both on the objects of the intervention (e.g., specific causal factors within the causal system) and on the methods to be employed in attacking those objects (e.g., modification of land-use decisions).
8. PROBLEM-DEFINING AGENT	A person whose values, aspirations, and perceptions result in the naming of some state of affairs as a problem. An individual may be classified as a problem-defining agent without being personally exposed to or part of this state of affairs. Thus, such individuals as environmentalists or legislators may be unaffected by an occurrent, but nonetheless define such occurrences as "problems."
9. PROBLEM-EXPERIENCING AGENT	An individual who experiences the effects of an event when the event or its effects have been described as constituting a problem. Such agents need neither disvalue nor even perceive the event or its effects in order to be so classified.
10. PROBLEM-DISCOVERING AGENT	A person who perceives a situation in which an event has occurred or will occur; in which effects are perceived to be experienced by some population at risk; in which the resulting state of affairs will deviate from that desired by some value holders (e.g., problem-definer) and in which the resulting gap between the desired and perceived states of affairs will indicate the existence of a problem. Problem-discovering agents need not, themselves, engage in acts of valuing, nor be personally committed to the reality perceptions held by others. Instead, such agents describe situations in terms of empirical reality of the perceptions of others, and of the values, aspirations, and problem-defining criteria of others.
11. CANDIDATE PUBLIC PROBLEM	A description of a situation which a problem-discovering agent or problem analyst believes will be viewed as a problem by some problem-defining agent or arbiter of social values. An arbiter of social values is one who has been socially vested with responsibility for judging the merits of competing values and for operationalizing those values in specific situations. All judges and legislators are, by definition, arbiters of social values.
12. IMPACT ANALYSIS	An impact analysis is a description and verification of the chains of effects and effect-experiencing parties linked to an event. The term, impact analysis, is intended to suggest the value-nuetral characteristics of such work. Not all effects of an event will be viewed as problems by the persons involved in that situation, even though they may be measurable and of large magnitude.

Figure 1-4. Definition of Critical Terms

TERM	DEFINITION
13. POPULATION-AT-RISK	The population of individuals or objects within which the primary, secondary, or higher-order effects of an event or phenomenon will be confined.
*14. RISK	The potential that some unwanted or negative consequences of an event will be experienced by some defined population. The potential is defined in terms of the probability that consequences of a particular severity will, in fact, be experienced by the population.
15. EXPOSURE TO RISK	The condition of being vulnerable to some degree to a particular outcome of an activity or event, if that outcome occurs.
16. RISK TAKER	A person or group of persons who enter into a situation in which there is a probability that some unwanted consequences will befall them. This group includes: voluntary risk takers and involuntary risk takers.
17. CONSEQUENCE VALUE	The importance of risk taker subjectively attaches to the undesirability of a specific risk consequence.
18. INEQUITABLE RISK	A situation in which a risk taker is exposed to a risk and receives no direct benefits from exposure, or in which the knowledge of the risk is purposely withheld from him.
19. MEASURED RISK LEVEL	The historic, measured, or modeled risk associated with a given activity.
20. PROBABILITY THRESHOLD	A level of probability occurrence for a risk below which a risk taker is no longer concerned with the risk and ignores it in practice. The probability threshold may also be viewed as the threshold of concern for some defined risk taker.
21. PROPENSITY FOR RISK ACCEPTANCE	A descriptor phrase intended to apply to some individual and which designates the degree of risk that individual is willing to subject himself or herself to for a particular purpose.
22. RISK ACCEPTANCE	The willingness exhibited by an individual, group, or society to accept a specific level or risk in order to obtain some gain or benefit.
23. RISK ACCEPTANCE LEVEL	The acceptable probability of occurrence of a specific consequence value to a given risk taker.
24. RISK ASSESSMENT	The total process of quantifying a risk and finding an acceptable level of that risk for an individual, group, or society. The process involves both risk determination and risk evaluation operations.
25. RISK DETERMINATION	The process of identifying and estimating the magnitude of risk.
26. RISK ESTIMATION	The process of quantifying the probabilities and consequence values for an identified risk.
27. RISK EVALUATION	The complex process of developing acceptable levels of risk to individuals or society.
28. RISK EVALUATOR	A person, group or institution that seeks to interpret a valuing agent's risk for a particular purpose.
29. RISK IDENTIFICATION	The observation and recognition of new risk parameters, or new relationships among existing risk parameters, or perception of a change in the magnitude of existing risk parameters.
30. RISK REDUCTION	The action of lowering the probability of occurrence and/or the value of a risk consequence, thereby reducing the magnitude of the risk.
31. RISK REFERENCE	Some reference, absolute or relative, against which the acceptability of a similar risk may be measured.
32. RISK REFERENT	A specific level or risk deemed acceptable by society or a risk evaluator for a specific risk; it is derived from a risk reference.
33. STAKEHOLDER	A party whose interests are assumed to be associated with the use or non-use of a technology in a specified situations. Stakeholders include a wide variety of definable parties, including: problem-experiencing parties; problem-defining parties; public policy makers; problem-solving strategists and analysts; beneficiary parties or groups; and others.
34. BENEFICIARY PARTY	In any given situation in which a problem has been defined, a beneficiary party is one whose self-interest will be advanced by the problem resolution even though that party is not itself an experiencer of the problem. Thus, the cement and construction industries are beneficiaries in situations where highway users are problem-experiencers.

*Definitions 14-34 are essentially as stated in Rowe, 1977.

Figure 1-4. Definition of Critical Terms (continued)

Focus of Study

Since all technology assessments are a part of public policy articulating processes, they require a focus on such subjects as:

(1) the socially-defined problems which are the interfaces between the technology assessment, public policy analysis, and the resultant acts of public policy making,

(2) the causal phenomena which are linked to these states of affairs,

(3) other problems and goals whose resolution may be impeded or whose accomplishment may be frustrated as a result of the side effects utilizing the technology, and

(4) the identification of stakeholders as well as those whose values are essential ingredients in the designation of some perceived state of affairs as constituting a "public problem" or in the designation of some desired state of affairs as constituting a "public goal."

Accordingly, the study which is the subject of this report was concerned with:

(1) Identification and description of the characteristics, geographic distribution, and potential effects of nine hazardous natural events within the United States (HAZARD ANALYSIS);

(2) Assessment of the vulnerability of several classes of buildings, and their occupants, to each hazard (VULNERABILITY ANALYSIS);

(3) Identification and measurement of the major primary, secondary, and higher order effects expected to be associated with the exposure, by major geographic area, of buildings and their occupants to these hazardous natural events (LOSS ANALYSIS);

(4) Identification and explication of the major candidate public problems which are associated with these effects (PROBLEM ANALYSIS);

(5) Identification of the costs and characteristics of the major types of technologies appropriate for mitigating the effects induced by exposure of buildings and their occupants to each of the nine natural hazards (TECHNOLOGY ANALYSIS);

(6) Identification and description of the major types of public policies which may induce the application of hazard-mitigating technologies (PUBLIC POLICY ANALYSIS);

(7) Estimation of the economic costs and other effects associated with the use of selected technologies to mitigate the effects of selected natural hazards (COST ANALYSIS);

(8) Identification of the major effects and candidate public problems which might be generated by the use of selected technologies to mitigate the effects of the nine natural hazards (PROBLEM ANALYSIS);

(9) Identification and evaluation of the major problem-solving strategies and public policies which are relevant to the problems identified in Items 4 and 8, above (PUBLIC POLICY ANALYSIS).

Objectives and Approach of Study

As depicted in Figure 1-5, the study was structured into four major and three minor elements. The latter included: hazard analysis, vulnerability analysis, and loss analysis. The former included risk analysis, technology analysis, problem analysis, and public policy analysis elements. The objectives and general methodologies of each of these major project elements are discussed below.

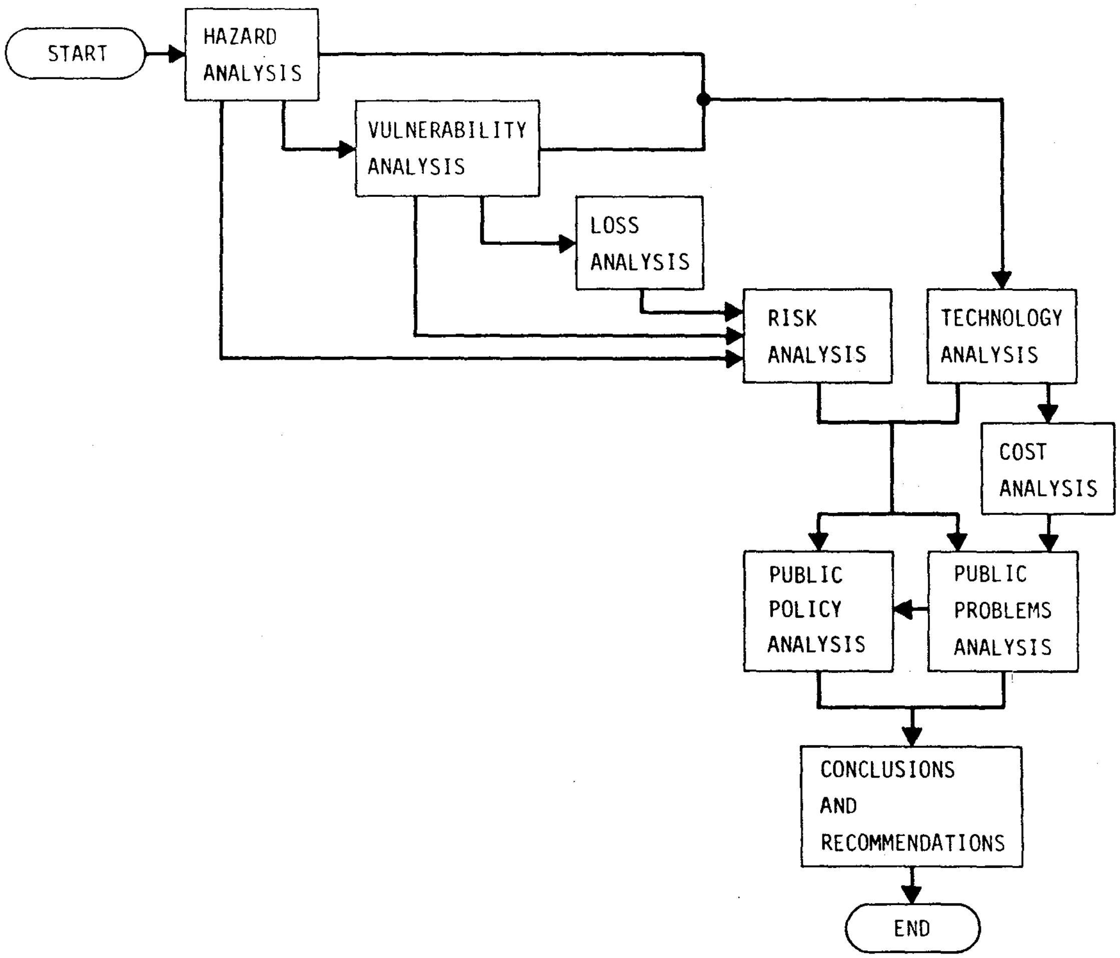


Figure 1-5. Relationship Between Major Project Activity Elements

Risk Analysis

The central element in the study was the risk analysis, whose major elements are depicted in Figure 1-6. The performance of this analysis required the development of computer-based hazard, exposure, and vulnerability models which were then used in concert with appropriate damage algorithms and risk equations in a series of separate studies, each concerned with a specific natural hazard.

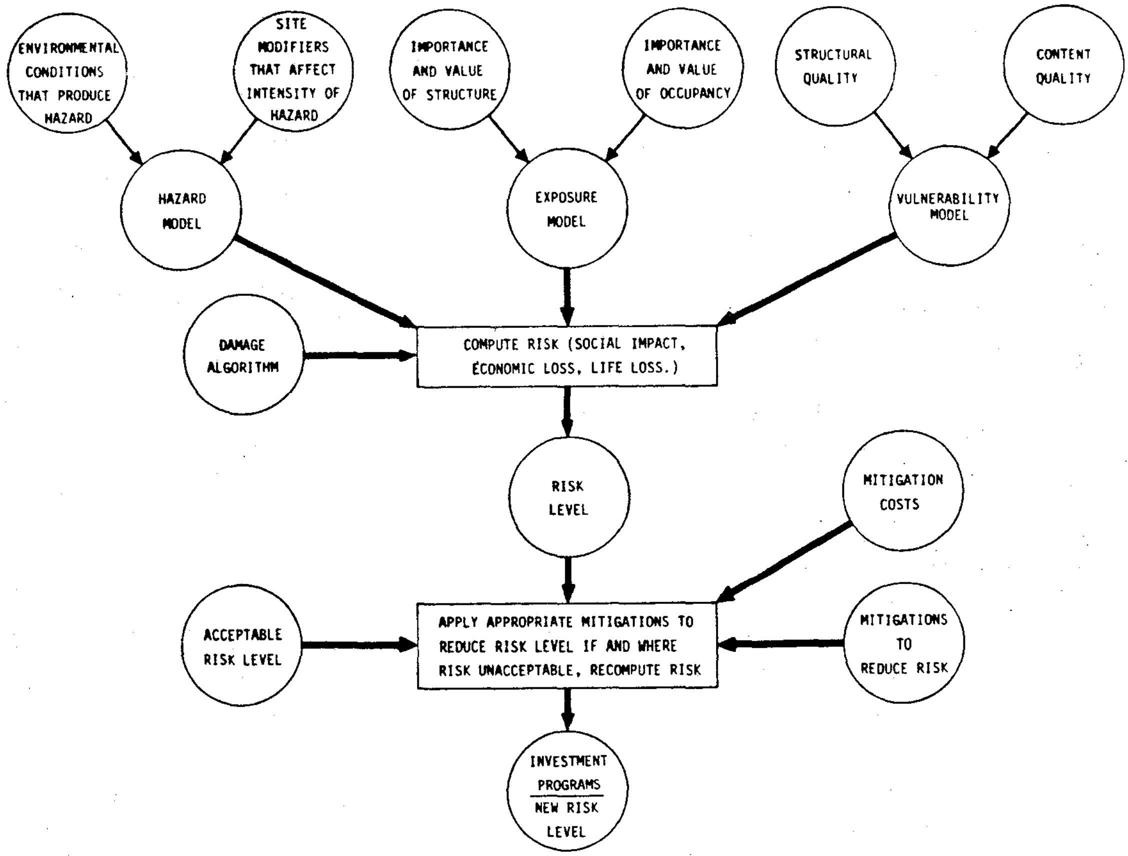


Figure 1-6. The Decision Process in Risk Evaluation

The analysis focused on nine natural hazards, including: earthquake, expansive soils, landslide, hurrican, tornado, severe wind, storm surge, tsunami, and riverine flooding. For each hazard, a computer model was developed to depict by county and state within the United States, the probability of hazard occurrence by hazard intensity. Where appropriate, the hazard models included both regional and site-modifier data, such as regional weather patterns and local ground elevation conditions.

The risk assessment for riverine flooding was confined to multi-state regional areas due to the characteristics of the model used. This basic model developed by D. Friedman for HUD [1966] and also employed in the loss analysis performed by the University of Colorado group under the direction of Gilbert White, was modified to provide for regional analysis.

The vulnerability element of the risk analysis involved the development of a computer-based exposure model for each hazard and appropriate damage algorithms related to various types of buildings. The exposure model included an inventory of the value of buildings and building contents, and the human population at risk in individual counties, sub-county hazard zones (where appropriate), and states, as well as data concerning the type and vulnerability of exposed assets within those areas. The damage algorithms which were developed stated the expected relationship between various hazard intensities and the degree and/or value of damage to structures of specific types. Typically, estimates of other types of losses such as death, building content loss, unemployment, and homelessness were related to the expected levels of damage to buildings in the prescribed areas.

The final risk equations utilized the damage algorithms and hazard, exposure, and vulnerability models to generate probabilistic annual estimates of dollar losses expected to arise from the exposure of buildings and building contents to natural hazard in the years 1970 to 2000. Except for riverine flooding, these data were generated, or are retrievable, at the scale of individual counties, states and the nation as a whole. The hazard-induced effects which were quantified by the risk analysis include: (1) economic losses to buildings (building losses); (2) economic losses to the contents of buildings (contents losses); (3) economic losses resulting from the lack of availability of goods and services to occupants of hazard-impacted areas measured in the form of transportation costs (supplier losses); (4) economic losses in the form of lost take-home pay from employment (income loss); (5) years of unemployment induced by hazard-caused damage to buildings and their contents (unemployment); (6) years of homelessness induced by damage to residences (homelessness); and (7) loss of life resulting from the occurrence of hazardous natural events (life loss).

The methodologies employed and the findings generated by the risk analysis are summarized in Chapters III, IV, V and VI of this report and are presented, in detail, in the following project reports:

"Natural Hazards: Storm Surge, Riverine, Tsunami Loss Models"
by Lee, Chrostowski and Eguchi

"Natural Hazard: Tornado, Hurricane, Severe Wind Loss Models"
by Hart

"Natural Hazard: Earthquake, Landslide, Expansive Soil Loss Models" by Wiggins, Slosson and Krohn

"Natural Hazards: Socio-Economic Impact Assessment Model" by Hirschberg, Gordon, and Petak

Technology Analysis

For each of the hazards studied, a preliminary list was compiled of the physical and management technologies of possible utility in mitigating the unwanted effects of building exposure to the hazard. These preliminary lists then were grouped, primarily for heuristic purposes, into seven major classes as follows:

(a) structural and other technical methods for minimizing the probabilities of hazard occurrences and for protection of hazard-prone land areas and building sites,

(b) structural methods for strengthening or protecting buildings which are exposed to hazardous natural events,

(c) methods for preparing building sites to limit the hazard exposure and hazard vulnerability of structures constructed on such sites,

(d) methods appropriate to the identification or avoidance of hazard-prone areas,

(e) hazard forecasting, warning, and population evacuation systems,

(f) loss recovery, relief, and rehabilitation systems, and

(g) information processing and decision-assisting methodologies useful in the selection and use of potential hazard-mitigating techniques.

Utilizing this classification scheme, a second examination then was made on each hazard, and relevant technologies were identified in each class for each hazard, where appropriate. See Chapters II and V of this report.

Cost Analysis

This element of the study responded to two information requirements: (a) the direct dollar costs associated with application of specific hazard mitigation technologies to specific types of buildings; and (b) the county-level cost/loss relationships which would be associated with mandatory community-wide use of specified hazard-mitigating technologies on specific types of new buildings.

Accordingly, the cost analysis was conducted in three steps: (1) building cost estimates, (2) county cost/loss ratio assessments, and (3) cost feasibility tests of selected mitigations.

Building Cost Estimates

For selected types of structures, literature reviews and surveys of expert opinion were conducted to identify the proportionate or absolute increase in cost that would be experienced were selected hazard-mitigating technologies applied to new buildings so as to reduce expected losses from earthquake, wind, and flooding. Typically these estimates were developed in a form capable of yielding crude estimates of the absolute or proportionate cost increases associated with structural design levels equal to given proportionate increases in the levels specified in the 1973 Uniform Building Code. However, other types of estimates also were developed or utilized, such as those relating to the cost of flood proofing, soil stabilization, etc.

County Cost/Loss Ratios

Utilizing these building cost estimates, a computer model was developed in order to generate estimates of total dollar costs which would be incurred were several structure-strengthening technologies to be applied to new buildings constructed between 1980 and 2000. The model also was designed to generate an expected cost/loss reduction ratio for mitigation of wind, storm surge, and earthquake hazard effects in the year 2000. This permitted us to identify those counties which, for these hazards, would experience ratios of costs-to-loss reduction of 0.75 and higher, were the designated mitigation technologies to be employed therein.

The cost/loss reduction ratios were calculated for each of the following mitigation technologies: (1) imposition of earthquake zone #3 building code standards in each county, (2) four-foot elevation of structures above flood plain levels, (3) two-foot elevation of structures above flood plain levels, (4) flood proofing of structures to two-foot elevations above level of flood plain, (5) escalation of building code standards to a level equaling 1.5 times UBC requirements for purposes of reducing wind losses, and (6) escalation of building code standards to a level equaling 3.0 times UBC requirements for purposes of reducing wind losses.

Cost-feasibility Tests of Selected Mitigations

Computer outputs and other data also were used to determine the annual amortized costs of various specific mitigations under a variety of interest rates. The results of these calculations were used to identify sets of cost-feasible hazard mitigations and the net annual savings (loss reductions) achievable through application of alternative hazard management programs and policies.

Public Problems Analysis

This phase of the study focused on the identification of those states of affairs which were revealed by the study as constituting candidate public programs. The data generated by the risk analysis and cost analysis components of the study were utilized in this effort, but were converted into forms more amenable to problem-oriented treatment. Thus, aggregated loss data by county and state were converted into per capita loss values and into other similar forms. Additional data concerning aggregated and per capita costs of other U.S. phenomena which generally are viewed as constituting public problems also were collected to serve as risk references. Further, an effort was made to identify specific loss situations which might differentially be valued by public policy makers and various stakeholders in situations where natural hazard-induced consequences can be expected. The results of this assessment are presented in Chapter IV.

Public Policy Analysis

This phase of the project focused on: (a) identification and review of major past and current hazard management policies; (b) identification of the socio-political-legal constraints which influence the making of hazard management public policy; (c) identification and explication of alternative public policies for dealing with each of the candidate public problems.

Principal among the technology-applying public policy actions which were addressed in this inquiry were: (a) building codes, (b) land use standards and regulations, (c) other selected regulatory policies, (d) land classification policies, (e) public capital investment policies, (f) public distributive and redistributive policies, and (g) public research, information dissemination, and education policies. Possible constraints influencing the capacity of each of the several jurisdictions of government to engage in policy-making in each class also were examined.

This phase of the study also examined the values, perspectives and biases which seem to have been associated with past acts of U.S. public policy-making relative to management of natural hazards and other related phenomena. Possible reasons for these characteristics of past decision practices were examined, and recommendations for new public policies to deal with the problems identified in the project were developed. The public policy analysis was performed, in part, by a team of policy analysts who had not been involved in the earlier phases of the study and who thus were somewhat freer to critically examine the significance of project data outputs.

Chapter Two

HAZARD CHARACTERISTICS AND MITIGATION TECHNOLOGIES

Introduction and Summary

Natural hazards are defined as those events which occur in nature and which are capable of producing injury or death to human beings and/or damage to structures and property. Human activities may alter the freguency with which such events occur, increase or reduce the severity or intensity of such events, alter the size of the area(s) impacted by such events, influence the rate of exposure of persons and/or property to the events, and influence the vulnerability of hazard-exposed persons and property. Vulnerability-altering activities always are referred to as "mitigations," but this term also applies to all other activities which are intended to alter hazard exposures, frequencies, intensities and impact.

Among the events which may be classified as natural hazards are: avalanches; earthquakes; expansive soils; forest, field, marsh and prairie fires of natural origins; hailstorms; hurricanes; landslides; riverine flooding; coastal storm surge and floodings; severe rain, snow, and ice storms; land subsidences; tornadoes; tsunamis; and volcanic eruptions. As a result of both natural and man-made factors, states, regions, counties, and urban areas of the United States differ widely in terms of the probability that one or more of these types of events will occur within their boundaries with any frequency over any given period of time. Similarly, large inter-area differences may be observed in the rates of population or property exposure and vulnerability to these phenomena.

Hazardous natural events may adversely impact human, animal and other biotic populations and may produce damage to a wide variety of property, including buildings, agricultural and forest resources, utility facilities, transport, and other community life-line facilities.

Nine specific natural hazards were selected for examination in this study earthquake, landslide, expansive soil, riverine flooding, storm surge, tsunami, tornado, hurricane, and severe wind. The study examined the effects of these hazards on exposed human populations and buildings. The following is a general discussion of the basic characteristics of each hazard and of the general technologies which can be applied to mitigate the effects of each.

Earthquake

An earthquake is a natural event which involves the moving or shaking of the earth's crust at some location. This moving or shaking of the earth's crust generally is believed to be caused by the release of stresses accumulated as a result of continuous collisions between the ten major and several minor plates which comprise the earth's 10-to-50 mile thick outer and floating crust. Earthquakes are measured in terms of seismic activity which is represented as magnitude or intensity.

The most common measure of earthquake magnitude, the Richter Scale, utilizes a nine-point logarithmic scale to present seismographic-recorded vibrational amplitude and energy release. On such a scale, each of the nine magnitude levels correspond to a ten-fold change in vibrational amplitude and a 3.15-fold change in energy release. In general, the greater the magnitude of an earthquake, the greater its damage potential. Approximate correlations have been developed between an earthquake's total energy in terms of pounds or tons of TNT and Richter magnitude [See Figure 2-1].

The direct and indirect effects caused by an earthquake are referred to as "seismic effects" and reflect the intensity of a quake. The most common system used to describe quake intensity is that contained in the Modified Mercalli Intensity (MMI) Scale. Structured around twelve levels of severity, the MMI Scale assigns a value of (I) to a barely-perceptible quake, a value of (VI) to a quake in which some momentarily-measured damage may occur, and a value of (XII) to one in which virtually total destruction may occur. In its current form, the Modified Mercalli Scale [See Figure 2-2] contains narrative descriptors of effects associated with various intensity quakes.

Seismic effects from earthquakes include ground displacement resulting from surface faulting or other abrupt earthquake-related land level changes; damage from ground shaking; ground failure such as lurching, soil liquefaction, differential settlement, landsliding, and abnormal water wave action (i.e., seiching in the case of inland lakes or tsunami in the case of ocean tidal action).

In general, the potential for damage from earthquakes in any given area is proportional to the actual energy released (magnitude of the quake), the distance

RICHTER EARTHQUAKE MAGNITUDE	APPROXIMATE EARTHQUAKE ENERGY
1.0	6 OUNCES T.N.T.
1.5	2 POUNDS T.N.T.
2.0	13 POUNDS T.N.T.
2.5	63 POUNDS T.N.T.
3.0	397 POUNDS T.N.T.
3.5	1,990 POUNDS T.N.T.
4.0	6 TONS T.N.T.
4.5	32 TONS T.N.T.
5.0	199 TONS T.N.T.
5.5	1,000 TONS T.N.T.
6.0	6,270 TONS T.N.T.
6.5	31,550 TONS T.N.T.
7.0	100,000 TONS T.N.T.
7.5	1,000,000 TONS T.N.T.
8.0	6,270,000 TONS T.N.T.
8.5	31,550,000 TONS T.N.T.
9.0	199,000,000 TONS T.N.T.

ENERGIES OF SOME MAJOR EARTHQUAKES

LOCATION	DATE	RICHTER MAGNITUDE	ENERGY (TONS OF T.N.T.)
ANCHORAGE, ALASKA	1964	8.5	31,550,000
SAN FRANCISCO, CALIFORNIA	1906	8.2	12,550,000
KERN COUNTY, CALIFORNIA	1952	7.7	1,990,000
EL CENTRO, CALIFORNIA	1940	7.1	250,500
LONG BEACH, CALIFORNIA	1933	6.3	15,800
SAN FRANCISCO, CALIFORNIA	1957	5.3	500

Source: AIA Research Corporation, Architects and Earthquakes U.S. Government Printing Office Washington, D.C., 1975

Figure 2-1. Energies of Earthquakes (Richter Magnitude 1.0-9.0)

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frames creak.

V. Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc. fall off shelves. Pictures fall off walls. Furniture moved or overturned. Weak plaster and masonry D (weak materials) cracked Small bells ring (church, school). Trees, bushes shaken (visibly) or heard to rustle.

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Some cracks in masonry C (ordinary workmanship and mortar, not reinforced). Waves on ponds; water turbid with mud. Small slides and caving in along sand and gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B (good workmanship, mortar and design; reinforced, designed to resist lateral forces). Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. Frame structures, if not bolted, shifted off foundations. Frames rocked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas, sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

* Richter, Charles F., Elementary Seismology, 1958

Figure 2-2. Modified Mercalli Intensity Scale of 1931, 1956 Version* of the area from the source of the energy release (epicenter), the local rock and soil characteristics of sites within the area, and the vulnerability of property to the resulting quake intensity. The earthquake "hazard" therefore, is based upon complex interrelationships between earthquake faults, weak geologic materials, and human activity in the earthquake prone region.

Determining the seismicity of an area requires far more than a review of historic records. Not only have accurate records of quakes been kept for only comparatively brief periods of time, but seismicity assessment also requires that attention be given to analysis of the geologic features of an area, such as the presence or absence of earthquake faults. Many of the known earthquake faults on the earth's surface are of no contemporary importance, are not now the site of earthquakes, and may, in fact, now be healed and as sound as the rock which surrounds them. Thus, Bonilla has observed that "most faults are not now the site of earthquakes ...are very ancient, and the absence of movement for hundreds of millions of years can be demonstrated for some of them" [Bonilla, 1970]. Nonetheless, many faults within the United States are active, are the sites of continued earthquakes, and exhibit considerable hazard to areas surrounding those faults.

When an earthquake occurs, the initial source of damage to buildings and other structures is a product of ground movements which cause structures to vibrate. During moderate ground shaking, the vibrations may be in the building's elastic range and exhibit no damaging amplitudes. During strong ground shaking episodes, however, building structural members may undergo plastic strains and the movement may therefore induce some cracking of these members. If severe enough, such cracking can result in the collapse of whole buildings and/or their major components. Also, wood frame buildings which are not securely anchored to their foundations, may be jolted off their mounts.

In almost all major U.S. earthquakes, structures most seriously damaged by ground movements have been unreinforced structures built from sand-lime-mortar brick bearing walls. Multi-story steel frame buildings have fared comparatively well, although extensive non-structural damage has sometimes occurred. In the Long Beach earthquake of 1933, the preponderance of deaths caused by the quake was the result of fallen cornices, building parapets, and ornamentation adorning multi-story buildings. Wood frame buildings sometimes have escaped quakes with little damage. However, during the 1933 Long Beach earthquake, a much larger than normal proportion of wood frame dwelling units experienced serious damage due to structural failures at or near the foundation level. These failures were a result of lack of lateral force bracing or from the deterioration of any such bracing that might once have existed. Nonetheless, about 95% of wood frame residences experienced less than 5% damage.

Mixes of avoidance and building strengthening strategies may be used to reduce the risk of building damage and life loss in seismically-active areas. Except for necessary utility and transportation lines, avoidance strategies call for complete avoidance of construction across fault lines and in areas immediately adjacent thereto. In such areas, land use should be confined to such purposes as agriculture or recreation. Outside such areas, building strengthening strategies may be employed. New structures of all types may be designed so as to resist damage from ground shaking and selected older buildings may be modified or abandoned. Earthquake resistance construction in engineered structures is achieved through the development of a design spectrum which is intended to specify the strength required of a structure in order to resist the forces expected to be produced on the structure as a result of vibrations expected at that site as a result of site-specific ground conditions and anticipated earthquake intensities. Such design spectra are constructed from knowledge of the observed performance of buildings during past earthquakes and these reference data guide the formulation of specific design criteria. In the design of important structures, such as 50-story buildings, nuclear power plants, large dams, long suspension bridges, and off-shore drilling platforms, complex dynamic analyses are required which involve the specifications of the design spectrum, the damping to be used, and the allowable design stresses. Standards which specify the required resistance of buildings to quake-induced lateral forces have been included in the Uniform Building Code and other state or local plans. Construction techniques appropriate for meeting such standards have been discussed by Whitman [1973], Culver, Lew, et. al. [1973], and others.

Landslides

Landslides are events in which surface masses of slope-forming earth move outward and downward from their underlying and stable floors in response to the force of gravity [Flawn, 1970]. Such movements include falls, creeps, flows, and slides and may be triggered by a variety of causal factors [See Figure 2-3].

In any of these events, the movement of the sliding, creeping, falling, or flowing mass of earth occurs whenever the "shear resistance" of the mass is exceeded by the "shear stress." The former term refers to the friction-induced binding of the mass to its floor, while the latter refers to the pull of gravity upon the mass. Shear stress may be heightened on a mass by steepening its slope or by increasing its weight, while shear resistance may be lowered by lubricating the interface between the mass and its floor.

Transitional or rotational slides are mass movements of earth which involve a distinct surface of rupture or zone of weakness which separates the earth slide material from a more stable underlying material. Generally, slides of this type occur anywhere that: 1) slopes are sufficiently steep to allow for lateral down-slope movement of materials in response to gravity; 2) there is an underlying zone of weakness as a potential surface of rupture; and 3) there is an intro-duction of a natural or man-made disturbing factor sufficient to initiate insta-bility and movement. Rapidly moving large slides of this type have the capacity to completely destroy buildings, roads, bridges, and other man-made structures as well as have the potential for inflicting loss of life if they occur in highly-urbanized or developed areas.

Having identified a region as being prone to these mass earth movements or land-slide failures, several approaches may be taken in an attempt to utilize the area. Designation of such areas as greenbelts, open space, or agricultural lands provides a means through which non-conflicting uses can be applied to the sites. If land development is a must, engineered design and construction techniques must be employed to secure correction of adverse conditions. This approach calls for careful evaluation of the seriousness and causes of geologic problems and a strict adherence to specific design and construction procedures set forth by competent professional geologists and engineers evaluating the landslide area.

Falls are common where there are cliffs of massive broken, faulted, or jointed bedrock; or where steep ledges are undercut by natural processes or activities of man. Falls, then, refer to the falling of soil or rock masses where a sliding

Name of Agent	*Event or Process Which Brings Agent into Action*	*Mode of Action of Agent*	*Slope Materials Most Sensitive to Action*	*Physical Nature of Significant Actions of Agent*	*Effects on Equilibrium Conditions of Slope*
Transporting agent	Construction operations or erosion	1. Increase of height or rise of slope	Every material	Changes state of stress in slope-forming material	Increases shearing stresses
			Stiff, fissured clay, shale	Changes state of stress and causes opening of joints	Increases shearing stresses and initiates process 8
Tectonic stresses	Tectonic movements	2. Large-scale deformations of earth crust	Every material	Increases slope angle	Increase of shearing stresses
Tectonic stresses or explosives	Earthquakes or blasting	3. High-frequency vibrations	Every material	Produces transitory change of stress	
			Loess, slightly cemented sand, and gravel	Damages intergranular bonds	Decrease of cohesion and increase of shearing stresses
			Medium or fine loose sand in saturated state	Initiates rearrangement of grains	Spontaneous liquefaction
Weight of slope-forming material	Process which created the slope	4. Creep on slope	Stiff, fissured clay, shale remnants of old slides	Opens up closed joints, produces new ones	Reduces cohesion, accelerates process 8
		5. Creep in weak stratum below foot of slope	Rigid materials resting on plastic ones		
Water	Rains or melting snow	6. Displacement of air in voids	Moist sand	Increases pore-water pressure	Decrease of frictional resistance
		7. Displacement of air in open joints	Jointed rock, shale		
		8. Reduction of capillary pressure associated with swelling	Stiff, fissured clay and some shales	Causes swelling	Decrease of cohesion
		9. Chemical weathering	Rock of any kind	Weakens intergranular bonds (chemical weathering)	
	Frost	10. Expansion of water due to freezing	Jointed rock	Widens existing joints, produces new ones	
		11. Formation and subsequent melting of ice layers	Silt and silty sand	Increases water content of soil in frozen top-layer	Decrease of frictional resistance
	Dry spell	12. Shrinkage	Clay	Produces shrinkage cracks	Decrease of cohesion
	Rapid drawdown	13. Produces seepage toward foot of slope	Fine sand, silt, previously drained	Produces excess pore-water pressure	Decrease of frictional resistance
	Rapid change of elevation of water table	14. Initiates rearrangement of grains	Medium or fine loose sand in saturated state	Spontaneous increase of pore-water pressure	Spontaneous liquefaction
	Rise of water table in distant aquifer	15. Causes a rise of piezometric surface in slope-forming material	Silt or sand layers between or below clay layers	Increases pore-water pressure	Decrease of frictional resistance
	Seepage from artificial source of water (reservoir or canal)	16. Seepage toward slope	Saturated silt	Increases pore-water pressure	Decrease of frictional resistance
		17. Displaces air in the voids	Moist, fine sand	Eliminates surface tension	Decrease of cohesion
		18. Removes soluble binder	Loess	Destroys intergranular bond	
		19. Subsurface erosion	Fine sand or silt	Undermines the slope	Increase of shearing stresses

Source: Broms, Bengt, "Landslides" in Foundation Engineering Handbook by Winterkorn and Fang (eds), Van Nostrand, Reinhold, New York, 1975.

Figure 2-3. Factors and Agents Influencing the Occurrence of Landslides surface does not occur. Fortunately, many rock fall areas can be identified and thus provide the opportunity to employ mitigation procedures. Generally, however, there are no reliable methods available to calculate the stability of a slope with respect to falls. Thus, falls can result in unpredictable and nearly instantaneous loss of life and property when people choose to live or develop structures in their paths without due consideration for the problem.

The most effective and least expensive way to mitigate the fall hazard is to avoid such areas entirely. There is no way to completely eliminate possible damage by falls. Thus human occupancy in an active fall area is generally incompatible with the idea of risk reduction. Certain techniques can be employed which may decrease the hazard somewhat; however, complete removal of all potentially unstable rock or material usually is not possible.

Flows are characterized by a situation where the surface material breaks up and moves down a slope and flows as a viscous fluid. Such types of flows are earthflows, mudflows, debris flows, flow-slides, and spontaneous liquefaction. The difference between the various types is generally considered to be the rate of movement.

Earthflows have been defined as slow movements of soft, weathered materials which develop, typically, at the toe of a massive landslide. Thus, earthflow represents a transition between a slide and a mudflow. Mudflows occur in areas where the particle sizes are predominantly silt and clay or fine sand with high pore water pressures. Mudflows in these soils are caused by erosion in the sand layers. Typically, they are recurrent events in drainage basins. Debris-flows occur in coarse-grained material; debris-flow is the term commonly applied to material consisting of boulder and cobble size stones mixed with displaced soil and vegetation. Such flows often develop in regions where the ground is not covered by vegetation and the area is subjected to heavy rainstorms or heavy floods.

Flows become serious threats only when people choose to live in active flow areas. Often there is little opportunity to provide warning with respect to flows in that they can occur as fast as a rising storm or a rapid increase in spring-time temperature. The consequences of improper utilization of flow areas range from occasional inconvenience to loss of life and total destruction of buildings or structures. Few flow-prone areas are suitable sites for construction of permanent structures. The unpredictable and often rapid movement of a flow makes even the location of a semi-permanent structure, such as a mobile home, very hazardous.

Flows can be channelized, diverted, or in some cases dammed. Generally, the cost will be very high relative to the amount of protection afforded. The principle difficulties associated with engineered structures to control mudflows are related to the great volume or mass of material contained in the flow. Because most of the flows consist primarily of heavy earth-matter, structures must be developed which are physically very strong and consequently very expensive.

Creeps are slow, down-slope movements of an earth mass. Although not dangerous to life, creeps may signal the onset of a potentially-dangerous slope condition and may require engineering control to prevent the earth mass from displacing structures or from moving over transport corridors.

Unstable or potentially-unstable slopes are defined as those areas which are susceptible to slides, falls, creeps, or flows. Among the factors contributing to slope instability are those of a topographic, climatologic, geologic, and hydrologic nature. Of these, the geologic properties of slope-forming materials are a primary factor determining the suspectibility of a slope to earth movements. Although such movements can occur in any type of rock material, certain bedrock formations or rock types exhibit a high susceptibility to such movement. These "adverse" materials include:

(1) Many of the younger (Mesozoic and Cenozoic) igneous (granitic) and metamorphic rocks found in the western United States have undergone intense fracturing and subsequent weathering. Therefore, these younger rocks generally have a greater propensity toward landsliding then many of the older, less fractured igneous rocks commonly found in the eastern portion of the country (i.e., New England States),

(2) Mesozoic and Cenozoic sedimentary rocks generally tend to contain large amounts of clay, especially montmorillonite. The presence of the clay material has a definite deleterious influence on slope stability.

(3) Many of the Cenozoic volcanic rocks in the western portion of the country appear to be landslide-prone in that they contain zones of montmorillonite (altered volcanic ash), in addition to being highly fractured and, in some cases, weathered.

(4) Serpentines consist essentially of secondary minerals normally derived by alteration of magnesium-rich silicate minerals. These materials, owning to inherently weak properties, are frequently susceptible to landsliding due to inherent weaknesses.

Landslides also occur in rock types other than those listed above. Therefore, all other known landslide-prone rock units either referred to in the literature or discussed by previously-mentioned data sources also were considered as being "adverse," for purposes of this study.

According to Terzaghi [1950], slides are caused both by internal and external factors. Internal causes are those which lead to sliding without any change in surface condition, and result primarily from an increase in pore water pressure and a concurrent decrease in cohesion. External causes include: over-steepening of the slopes; addition of weight from materials placed along the upper portions of slopes; added weight from increased moisture content; and seismic or man-induced vibrations.

Human activities, of course, can lead to the occurrence of these slide-inducing external and internal causal factors. One means for controlling the human activities which lead to these outcomes is through subdivision and building codes which contain stringent soil testing, site-grading, and site avoidance requirements. For example, Slosson [1977] has presented information showing the impact of such codes on reduction of landslide losses within the City of Los Angeles. He reports that, prior to 1952 when no grading codes existed and soils engineering and engineering geology reports were not required of hillside subdividers, approximately 1,040 sites were damaged out of 10,000 landslide-prone sites on which construction had taken place. This represents a 10.4% failure rate. When semi-adequate grading codes and soils engineering reports were required between 1952 and 1962, the number of damaged sites totaled only 350 out of 27,000 sites on which construction had taken place. This represented a 1.3% rate of failure.

During the period of 1963 to 1969 (when modern grading codes were utilized and soils engineering and engineering geology reports were required), damage occurred on only 17 sites out of approximately 11,000 on which construction took place, for a 0.15% failure rate. These data suggest that landslide damage losses can be reduced significantly through application of effective grading ordinances or codes. In the City of Los Angeles, for only minimal cost, the monetary losses resulting from landslides were reduced by approximately 97% through application of this type of mitigation [Slosson and Krohn, 1977].

Expansive Soils

Although all soils experience some shrinking and swelling as a function of variations in the moisture content of their environments, excessive shrink-swell behavior can produce the cracking and/or failure of building walls, foundations, slabs, and veneers.

Expansive soil generally refers to soil and rock which contains clay materials with the capacity of undergoing significant volumetric changes when subjected to variances in water content. That is, when the water content is increased, the soil will swell and when the water content is decreased, the soil will shrink. The degree of shrink-swell capacity of any given soil is related to the proportion of clay contained in the soil and more specifically to the proportion of active clay materials such as montmorillonite (bentonite). A sample of pure montmorillonite can swell up to 15 times its dry volume. However, due to the fact that most natural soils are a mixture of various clay materials, few swell to more than 1 1/2 times their original volume.

One measure of the shrink/swell potential of soils, the Coefficient of Linear Extensibility (COLE) has been developed by the U.S. Soil Conservation Service. The coefficient represents an estimate of the vertical component of swelling in a natural soil clod. Soils with coefficients lower than three percent are judged to rank low in soil expansion capability; those between 3.0 and 6.0% are judged to be moderate; and those with coefficients greater than 6.0% are judged to rank high in this capability. The higher the coefficient, the more severe the shrink/swell behavior of a soil is likely to be; the greater the shrink/swell behavior, the greater the damage potential to buildings and other structures.

Expansive soils can be tentatively identified by visual observation and generally positively identified by appropriate laboratory testing. Although various visual methods for identification exist, only a professional soils engineer, or engineering geologist should be relied upon to identify this potential hazard. Jones [1976] has provided some clues which can help to identify naturally-occurring, potentially-expansive soils. These criteria for recognition are depicted in Table 2-1.

DRY CONDITIONS

- SOIL HARD AND ROCK LIKE; DIFFICULT-TO-IMPOSSIBLE TO CRUSH BY HAND.
- GLAZED, ALMOST SHINY SURFACE WHERE PREVIOUSLY CUT BY SCRAPER, DITCHER TEETH OR SHOVEL.
- VERY DIFFICULT TO PENETRATE WITH HAND PICK OR SHOVEL.
- GROUND SURFACE DISPLAYS CRACKS OCCURRING IN A MORE OR LESS REGULAR PATTERN.
- SURFACE IRREGULARITIES, SUCH AS TIRE TRACKS, CANNOT BE OBLITERATED BY FOOT PRESSURE.

WET SOIL CONDITIONS

- SOIL VERY STICKY AND CLINGING; EXPOSED SOIL WILL BUILD UP ON SHOE SOLES TO A THICKNESS OF FROM 2" - 4" WHEN WALKED UPON FOR A SHORT DISTANCE.
- CAN BE EASILY MOLDED INTO A BALL BY HAND; HAND MOLDING WILL LEAVE A NEARLY INVISIBLE POWDERY RESIDUE ON HANDS AFTER THEY DRY.
- A SHOVEL WILL PENETRATE SOIL QUITE EASILY AND THE CUT SURFACE WILL BE VERY SMOOTH AND WILL TEND TO BE SHINY.
- FRESHLY MACHINE SCRAPED OR CUT AREAS WILL TEND TO BE VERY SMOOTH AND SHINY.
- HEAVY CONSTRUCTION EQUIPMENT, SUCH AS METAL WHEELS AND COMPACTING ROLLERS WILL DEVELOP A VERY THICK SOIL COATING THAT MAY IMPAIR THEIR FUNCTION.
- IN SEMI-ARID AREAS HAVING DISTINCT WET AND DRY SEASONS EXPANSIVE SOILS THAT HAVE BEEN UNDISTURBED FOR 10 - 15 YEARS OR MORE MAY DISPLAY A PATTERN OF CLOSED RIDGES SPACED REGULARLY ON 10 - 50 FOOT CENTERS

ANY CONDITION

- CREEP RIDGES (VISIBLE EVIDENCE OF SOLIFLUCTION) ON SLOPES; GENERALLY AN INDICATION OF INCIPIENT SLOPE INSTABILITY AS WELL AS POTENTIALLY EXPANSIVE SOIL.
- TOPS OF FENCE POSTS TILTED DOWNHILL; THIS MAY GIVE OBVIOUS INDICATIONS OF DOWNHILL CREEP MOVEMENT IN SITUATIONS WHERE SOLIFLUCTION PATTERNS ARE INDISTINCT.
- EXTENSIVE VISIBLE CRACKING IN WALKS, STREETS, DRIVEWAYS, PATIOS AND OFTEN IN BUILDINGS; THIS DOES NOT ALWAYS MEAN THAT EXPANSIVE SOILS ARE PRESENT, BUT THEY OFTEN ARE WHEN SUCH SYMPTOMS ARE VISIBLE.

Table 2-1. Recognition Criteria for Expansive Soils [Jones, 1976]

Expansive soils are a nation-wide problem and so common in urban areas that complete avoidance as a means of mitigating the hazard is generally unfeasible. However, the widespread distribution of swelling soils must be recognized and precautions must be taken to require special engineered foundations and floor system designs, as well as detailed maintenance procedures in order to protect owners in affected areas. Engineered design and soil stabilization are considered the only appropriate corrections of these adverse conditions. Thus, expansive soil damage can be minimized by combinations of engineered foundation design, well-planned site grading and drainage, landscaping to enhance drainage, and careful interior construction details.

The shrinking and swelling of expansive soils under changing weather conditions can damage a great variety of structures and community facilities. Streets, sidewalks, utility lines, airport runways, building foundations, and building slabs all can be damaged by the shrink-swell activities of expansive soils. Ordinarily, however, damage usually is limited to non-engineered structures in which inappropriate consideration has been given to protecting the structure from expansive soils problems. Expansive soils damage may be minimized by a combination of five methods: (a) use of soil stabilization and moisture control techniques on building sites, (b) engineered foundation design, (c) well-planned site drainage systems, (d) landscaping to enhance drainage, and (e) careful attention to interior construction details. Rogers, et al [1974] has discussed four of these techniques, as follows:

(1) Foundation design. In areas of relatively low swell potential, spread footings are commonly used. For slightly higher swell pressures, extended bearing walls or pads may be used. In areas containing moderate to highly-swelling clay, drilled pier and grade beam foundations are used. The weight of the building is transmitted through bearing walls to horizontal grade beams. These beams rest on cylindrical, reinforced-concrete piers that concentrate the weight on a very small area below the zone of seasonal moisture change. The foundation is thereby founded upon soil that, because its moisture content remains constant throughout the year, should not experience a volume change.

With each of these special foundation designs, floating slabs are commonly used for all on-grade floors. The interior concrete floor slabs are completely isolated by joints or void spaces from all structural components. Complete isolation from bearing walls, columns, non-bearing interior partitions, stairs, and utilities allows the slab to move freely without damaging the structural integrity of the building. In the Denver area, swelling soil below the level of the proposed floor slab is sometimes excavated to a depth of several feet and replaced by various kinds of engineered backfill.

Pre-construction chemical soil stabilization utilizing lime or organic compounds may reduce the potential of swelling soil damage more economically than the utilization of structural floors and special foundations. The chemical stabilization technique has a short history and limited use in Colorado. Where it has been used, it appears to have been successful for the period of time since application.

(2) Drainage. The Federal Housing Administration recommends slopes of no less than six inches of vertical fall in ten feet (12 inches in ten feet is safer) around all buildings for drainage [Federal Housing Administration, 1966]. These slopes must drain water into drainage swales, streets, or storm sewers. Water must not be allowed to stand near foundations in areas of swelling clay due to the potential for wetting foundation soils. All downspouts and splash blocks should be placed so that roof runoff will be carried at least four feet from the building. In areas of heavy lawn irrigation, peripheral drains have proven effective in preventing the formation of perched water tables and the resulting downward seepage of surface water [Sealy, 1972]. The clay-tile or perforated plastic peripheral drains completely surround the building just below the level of floating floor slab. There is some question, however, as to their reliability. The drain is placed on heavy plastic film that is glued to the foundation wall and covered with washed gravel and felt paper. The drain is normally connected to a storm sewer (where legal) or at a gravel-filled trench so that water can be carried away from the structure.

(3) Landscaping. Proper foundation design and construction will not solve all swelling-clay problems. The owner of a structure is responsible for maintaining proper drainage by careful landscaping. Backfill around foundations is often not properly compacted. Therefore, additional soil may be required on the slope around the structure in order to compensate for settlement of the backfill. This prevents "ponding" and percolation of water around the foundation. Asphalt, concrete, or gravel-covered plastic sheeting should be placed around the entire foundation at a two-foot depth. These four-foot or wider strips prevent surface moisture penetration and excessive desiccation cracking near the building. Grass, shrubs, and sprinkler systems should be kept at a minimum of four to five feet from the foundation. Trees should be planted no nearer than

15 feet from a building. The most critical aspect of landscaping in swelling clay areas is not to flatten a properly designed slope.

(4) Interior finishing. One of the most costly mistakes a homeowner or careless contractor can make is to defeat the design purpose of a floating floor slab. A floating garage or basement floor slab is designed to move freely. Therefore, any furring, paneling, dry wall, or interior partitions added to a basement or garage must maintain this freedom of vertical movement. Any added walls or wall coverings should be suspended from the existing walls or ceiling, and should not be attached to the floor slab. A minimum void space of three inches should then be provided just above the floor slab. This void space may be covered with flexible molding, or inflexible molding attached to the floor rather than the wall. Although these recommendations provide for three inches of upward swell of the soil beneath the floor slab, more void space may be necessary in areas of highly-swelling clay.

Similarly, Winterkorn [1975], has pointed out that the lime treatment of clay soils sharply decreases the lineal shrinkage and swell capacity of such soils and can therefore prepare soils to serve underneath all types of pavements and other constructed works.

It must be noted, however, that lime, when freely blended with a reactive montmorillonite clay, will only stabilize the clay it is mixed in. Generally this procedure is far too expensive to apply at any appreciable depth.

Riverine Flooding

Since the earth took its present form, the periodic flooding of lands adjacent to streams and rivers have been an ever-present characteristic of the human geophysical environment. Caused by stream flows which exceed the capacity of the normal water course, riverine flooding involves the spill-over of above-normal stream flows onto the lands immediately adjacent to the normal water course. Those adjacent lands which are subject to such intermittent flow-determined flooding are referred to as the stream or river's floodplain.

Hydrologically, stream flow is measured in terms of thousands of cubic feet of water flow per second and a flood is defined as any stream flow event in which the flow exceeds the capacity of the normal watercourse. Such events are probabilistic phenomena. Assuming no change in the stream flow capacity of the normal water course, these events are a function of precipitation levels and water-run-off volumes within the watershed of the stream or river. The recurrence interval of a flood is defined as the average time interval, in years, which may be expected to lapse between the occurrence of a flood of a specified magnitude and an equal or larger flood. For any given river or stream, a specific peak flow level is associated with each flood recurrence interval for the stream (flood return period) and the return period of the event is viewed as the measure of the magnitude of the event.

That portion of the stream's flood plain which will be inundated by spill-over waters resulting from a stream flow level of a specified flood-return frequency is referred to by the name of that frequency interval. Thus, a flood having a two-year return period will inundate all of the two-year zone of the flood plain, and a flood having a 100-year return period will inundate all of the 100-year zone of the flood plain. For land use purposes, flood plains can be divided into six levels of flood classes, or six hazard zones: A through F (where A is the most hazardous [e.g., subject to most frequent flooding in any 100-year period] and F the least). These zones constitute the areas that would be inundated by the 2-5, 5-10, 10-25, 25-50, 50-100, and greater-than-100-year floods. Along any section of any given river, local terrain characteristics and stream factors determine the geographic size of the flood plain, the size of any given zone within the flood plain, and the depth that flood waters will reach over the lands comprising any given flood plain zone during a flood of specified magnitude (return period).

Flood plain occupancy poses a major dilemma. Flood plains generally provide attractive locations for man's activities. Historically, man has found attractive the rich alluvial soils, easy access to transportation, and the general convenience and amenities of living near major rivers. This has resulted in the development of some of the world's greatest civilizations in the bottom lands of major rivers. Certain activities require a riverine location, such as those dependent on water for transportation, industrial processing and cooling. Water-dependent activities have, however, attracted other activities into these locations such as recreational facilities and housing. Flood plains have, therefore, become the site of a considerable portion of the nation's land development and economic activities.

In terms of the structures which are located within any flood zone, the damage which will be sustained by the structures during flood episodes is a function of: (1) the type, strength and elevation of the structure, and (2) the depth of the flood waters during the episode. The damage which is sustained by structures during a flood is a product of several sets of factors, including: (1) the force exerted against the structures by the moving flood waters, (2) impacts of floating debris against the structures, and (3) the adverse "wetting" effect of the structure and the contents which are produced by the intrusion of flood waters into the structure.

Measures for mitigation of flood hazards may be classified into three broad categories: (a) structural mitigations which involve the construction of area-protecting dams, dikes, levees, and/or the deepening or improvement of the normal water course (floodway), (b) avoidance mitigations which prevent or deter the occupancy of flood-prone lands, and (c) building mitigations which include such specific measures as the elevation, strengthening, and/or flood proofing of structures which are located with the flood plain. A fourth category of possible mitigation involves the application of means for reducing the rates of water runoff from land areas during storms. Obviously, as these runoff rates are increased through such human activities as the paving of land areas, the "normal" flood flow is increased and the magnitude of the hazard is enlarged.

Specific building mitigations which have been suggested by Johnson [1978] for application to flood plain structures, include: installation of temporary or permanent closures for openings in structures, raising structures in-place, constructing new structures on fill or columns, constructing small walls or levees around structures, relocating or protecting damageable property within existing structures, and use of water-resistant materials in new or existing structures.

Storm Surge

A storm surge is an event in which the coastal water level rises above the level associated with normal tidal action. The most heavily-affected areas of the United States are the Atlantic and Gulf coasts. Increases in water level along the Gulf and Southern Atlantic coastline generally are caused by hurricanes and other less intense tropical storms. Along the northern Atlantic coastline storm surges are caused mainly by extra tropical winter storms called "Northeasters."

When these storms approach land, extremely large waves may be superimposed on the high waters moving toward the coast. The depth of the surge is dependent upon a complicated set of interactions between the path, intensity, speed, and size of the storm, as well as the configuration of the sea bottom and coastline. Local conditions often cause a depth variability of several feet within a distance of a few miles [Friedman, 1966].

The tropical weather storms which produce storm surges usually are classified into three categories: 1) tropical depressions with maximum wind speeds less than 40 mph, 2) tropical storms with maximum wind speeds of 40 to 73 mph, and 3) hurricanes with maximum wind speeds in excess of 73 mph. The coastal storms of the northeast are extratropical in nature, with wind speeds below the hurricane level.

The most devastating storm surges are caused by hurricanes. Hurricanes originate in tropical climates where atmospheric conditions are entirely different than those in the temperate zone [Maldus, 1957]. As a hurricane or coastal storm approaches the coast, the normal water level can be altered by five distinct processes [Harris, 1963].

(1) The pressure effect - the low central core pressure of a hurricane or tropical depression causes the water level to rise. A pressure drop of one inch of mercury will cause the water level to rise approximately 13 inches in the open ocean.

(2) Onshore wind effect - the winds affecting coastal areas can be broken into two components - one normal (onshore) to the coast, and one parallel (alongshore) to the coast. Onshore winds from the normal component cause water to pile up at the shoreline. This effect, often called the "wind set-up" may be particularly pronounced in shallow bays and estuaries.

(3) Coriolis effect - the earth's rotation produces acceleration in a westerly direction on objects moving from the equator towards the north pole. Thus, alongshore currents produced by alongshore winds can be forced towards the shore.

(4) Wave effect - the energy possessed by surface waves moving in open waters is not significant. But as they approach coastal areas, the rapid decrease

in water depth creates fast moving waves. As they strike the shore, their momentum may cause run-ups with surge heights up to twice that of the wave itself. The waves may also cause a piling up of the water near the shore producing a "wave set-up" analogous to the wind set-up.

(5) Rainfall effect - hurricanes can dump as much as twelve or more inches of rain in 24 hours over large areas. This excessive rainfall can often cause a significant rise in coastal water levels, especially in estuaries, bayous, and other coastal wetlands.

Storm surges generally are associated with two types of damage: (1) still water effects associated with simple inundation of a structure or land area and, (2) wave action effects induced by the pounding of waves against a structure. Inundation (stillwater) damage is very similar to that caused by riverine inundation of corresponding depths, except for the increased damage which results from the more corrosive effects of salt water. Once a structure has been "salted" the hygroscopic nature of salt will forever keep the structure moist, causing continuing mildew, corrosion, and other damage to the buildings and its contents. The depth of the storm surge wave, as modified by local marine factors, determines the size of the area which will be inundated, and the height of the inundation above mean sea level. The latter is the major factor in determining the "stillwater" damage which will be sustained by a structure constructed in any given elevation above mean sea level.

Storm surge mitigations include the avoidance and building mitigations which have been identified as applicable to riverine flooding. In addition, construction of seawalls is a strategy that can be used to provide protection to whole areas within storm surge zones.

Tsunami

A tsunami, or seismic seawave, is a large oceanic wave which is produced by an earthquake, a submarine volcanic eruption, or by a large submarine landslide. The waves that are generated by such an event are formed in groups having great length from crest to crest and having long periods. In deep oceans, wave lengths may be 100 miles or more, while wave heights, from crest to trough, are only a few feet. Nevertheless, the intrinsic wave energy is impressively great.

As a tsunami enters shallow waters in the coastal areas, the wave velocity diminishes and the wave height increases. The water which runs up onto the land is measured in terms of runup elevation, the elevation above the tide level at the time of the tsunami. If the trough precedes the initial crest, the arrival of the tsunami is first noticed by a gradual recession of coastal waters; if a crest precedes, there is a rapid rise in water level. Waves which follow the initial wave can crest at heights of more than 100 feet and strike with devastating force [Hwang and Divoky, 1971].

Few studies have been made of the forces which are exerted by tsunami waves when running up onto the land. These forces present a difficult problem in that no actual measurements have been made and only a few estimates of forces are available [Weigel, 1970]. Damage resulting from tsunami is a result of two factors: (1) inundation and (2) the force exerted on structures by the impacting wave. Damage can be very great, and, in addition to loss of life and damage to buildings, extensive damage often occurs to boats that break and drag their moorings and pound against other boats in the docks, or against buildings as they are carried ashore by the tsunami waves. The forces associated with tsunamis are often so great that the only positive means of protection for most structures is to avoid areas subject to impact by a tsunami event. In some areas of the Hawaiian Islands subject to tsunamis, very large and significant structures are being constructed, but designed so as to withstand tsunami forces. For example, the interiors of the lower portions of the structures have been designed so that they are breakaway and expendable, while the structural support elements (i.e., vertical columns) are designed to withstand the force. The U.S. Government has set criteria for nuclear power plants requiring structures to be designed for and constructed to withstand the greatest possible tsunami.

In the last 50 years, more lives have been lost from tsunamis in the United States than directly from seismic activity. In 1946, a tsunami generated near the Aleutian Islands killed 173 persons in Hawaii, and in 1964 the tsunami in conjunction with the Alaskan earthquake killed 126 people. Therefore, if man is to continue to live in the coastal zones, it is important that the risk associated with a tsunami event be given full consideration prior to coastal land development.

A first step in developing effective plans for mitigating the tsunami hazard is to define local impact or damage areas. Detailed studies of the shoreline, harbor areas, and ocean bottom configurations are necessary for the accurate determination of areas subject to tsunami inundation. Only when the risk areas have been determined should methods for protecting lives and property be instituted.

Tornadoes

The term tornado comes from the Spanish "tornada", meaning thunderstorm, and was derived from the Latin, "tornare", meaning to "make round by turning." These events generally are defined as violently-rotating columns of air which are in contact with the ground. A tornado is visible as a cloud base or as a rotating dust cloud rising from the ground.

Tornadoes are the most violent windstorms or weather phenomena known to man. Rotating at velocities up to 500 mph, their funnel-shaped clouds can affect areas ranging from 1/4 to 3/4 of a mile wide and upwards of 16 miles long. Extreme events have been known to travel over areas measuring up to one mile wide and 300 miles long. Tornadoes have been recorded in every state, but the midwest and southeast are the most vulnerable areas. While tornadoes have been known to occur throughout the year, weather conditions between April and June generally produce the greatest number of events. No other disaster associated with the weather strikes with the suddenness of a tornado.

Tornadoes may form in association with squall lines, with both isolated thunderstorms and thunderstorms accompanying frontal passages, and with hurricanes. As the storm system moves, one or more tornadoes may form at intervals along the path, travel a few miles, lift and then appear further down the track. Small vortices may travel around a main tornado axis with as many as five of these satellite vortices having been observed in a tornado at one time. The main vortex of the tornado has tangential, radial, and vertical air flow and an associated atmospheric pressure drop.

Lasting minutes or hours, tornadoes exhibit much higher wind speeds than hurricanes but affect smaller impact areas. One system for measuring the intensity of a tornado is the Fujita classification, which assigns a numeric value to a tornado based on its wind speed, broken down into 1/4 mph increments. Still another, the Pearson Scale, uses an identical scheme to classify tornadoes by their path width and length. The combination of these two systems is the FPP classification system [Fujita, 1970] and [Fujita and Pearson, 1973].

For any building type, the damage expected to result from exposure to a tornado increases as a function of the Fujita rating of the occurrence. Thus, a Fujita rated 5 tornado (F5) would be expected to cause the collapse of 65.0% of all exposed wood frame commercial and industrial structures while Fujita-rated 1 tornado (F1) would cause the collapse of only 1% of such structures. The following figure provides a general realtionship between Fujita rating and damageability.

DISTRIBUTION OF RECENT TORNADOS	20%	43%	25%	9%	3%	
TYPE OF DAMAGE	LIGHT	MODERATE	CONSIDERABLE	SEVERE	DEVASTATING	INCREDIBLE
FUJITA RATING	F0	F1	F2	F3	F4	F5

Source: Abernathy, 1976

Figure 2-4. General Fujita Rating-Damage Relationship

Tornadoes are so violent and destructive that they were frequently identified as the "number 1" natural disaster killer in the United States. During the past 50 years, 9,000 deaths have been attributed to tornadoes. [Executive Office of the President - Office of Emergency Preparedness, 1972].

Since tornadoes are localized,low-pressure storms in an overall low pressure system, the atmospheric pressure inside a building will greatly exceed the outside pressure. This differential will cause a building to tend to explode. Building explosions have, however, been greatly overstated. Almost all damage can be explained to result from the extreme winds and flying missiles [Abernathy, 1976].

Mitigating the effects of tornadoes is extremely difficult. Little can be done to keep structure development and population out of the path of a tornado, since the events are random, and significant wealth is already at risk in the more tornado-prone areas. However, the vulnerability of damageability of structures exposed to tornadoes may be reduced through the use of building-strengthening technologies. This means that mitigations should concentrate on improved structural design. New buildings may be designed for greater lateral load-carrying capacity, storm cellars may be constructed, old buildings may be reinforced, mobile homes may be tied down, and windows may be boarded up.

Experience has shown that short spans on the roof or floor structures easily remain intact after an event, due to the fact that short spans limit the amount of uplift caused by the winds. Framed construction also usually remains intact. Any structural system, rigidly framed together, tends to be superior to long load-bearing walls. Reinforced concrete, poured-in-place, will usually withstand the storm. Also rigidly-connected frames will withstand tornado forces. However, it is important in both the poured-in-place concrete and the steel frame construction that roof and floor systems be securely fastened to the supports. Generally, the heavier the floor or roof system, the more resistant it is to uplifting forces. Windows are no match for the extreme winds or missiles in a tornado. Also in order to reduce the pressure differential on the building, it is proper to open windows, especially on the leeward side.

Hurricanes

Hurricanes are defined as devastation by wind, flood producing rain and the most lethal of all, the storm surge. For purposes of this discussion, however, only hurricane wind is discussed.

Hurricanes are large cyclones of air in which the counterclockwise-spiraling winds move around a relatively calm center (the core or eye) at speeds of 73 miles per hour or more. Formed in the tropics, the typical hurricane system measures about 400 miles in diameter, moves at a forward speed of about 15 miles per hour and has an average life span of about nine days. The highest wind speeds in a hurricane system are measured approximately 20 to 30 miles from its center. The highest wind speed recorded in any hurricane was 197 miles per hour (Hurricane Inez) but gusts between 73 and 120 miles per hour can be expected to extend 40-100 miles from the center.

Hurricanes differ from tornadoes in the following respects: 1) the change in pressure associated with the passage of a hurricane over a structure is rather gradual and has very little effect on the structure, whereas the change in pressure associated with the passing of a tornado is very large, often causing structures to literally explode, 2) hurricane wind speeds are generally much smaller than those of a tornado, 3) while both wind storms are rotating air masses, the hurricane rotating air mass covers a much greater area. The vertical wind speeds in hurricanes are very low in comparison to tornadoes. Thus, hurricanes have little capacity to hold aloft and transport large, heavy objects.

Considerable effort has been made in recent years to learn more about hurricane occurrence, particularly the work of Ho, Schwerdt, and Goodyear [1975]. The most significant portion of the United States coastline at risk is along the Gulf and Atlantic Coasts. Since the beginning of the 20th century, despite the increasing population density in this area, the number of lives lost due to hurricane has been decreasing. This has occurred as a result of improved prediction and warning systems. However, property losses continue to rise. There is continuing concern that the increasing population, along with ineffective building codes, may lead to a major hurricane disaster along the Gulf or Atlantic Coasts.

Hurricane damage to buildings is predictable. However, even the most modern building codes do not require buildings to withstand the extreme winds of a hurricane. As such, hurricane-resistant building standards should be implemented within the identified hurricane hazard zones. These minimum standards should include the same mitigations recommended for tornadoes.

Severe Winds

Severe winds are those windstorms which exceed 50 miles-per-hour velocity, but which are not associated with hurricanes or tornadoes. Severe windstorm can occur in virtually any area of the United States. As such, a minimum building code should be the requirement in order to protect structures from severe wind damage. Damage associated with the severe wind hazard is typical of that associated with lower velocity hurricanes and tornadoes. Thus, similar mitigations should be employed.

Approaches to Mitigation of Natural Hazards

Seven distinct approaches may be taken, alone or in combination, to mitigate the effects of natural hazards:

(1) Approaches which involve measures to minimize the probability of hazard occurrence (abatement) and/or to protect areas and building sites from the hazard (area protection). Actions which are intended to minimize the runoff of heavy rain waters are illustrative of the former, while the construction of dams and levees are illustrative of the latter.

(2) Approaches which focus on the strengthening of buildings exposed to hazards or which focus on site level systems for protecting buildings from such hazards. Small levees around structures and floodplains are illustrative of the latter, while use of shear panels to protect frame buildings from earthquake vibrations are illustrative of the former.

(3) Approaches which give attention to site-development schemes for protecting structures from hazards. Suggestive of this approach is use of more appropriate grading practices to protect against landslides, and use of soil stabilization methods to limit the shrink-swell behavior of potentially building-damaging soils.

(4) Approaches, such as floodplain mapping and restrictive floodplain zoning, which involve the identification of hazard-prone sites and the use of means to prevent their development and use.

(5) Loss recovery, relief, and community rehabilitation approaches. Illustrative are floodplain insurance programs and the low interest loans authorized by the Federal Disaster Relief Act.

(6) Hazard warning and population evacuation systems, such as those employed to deal with approaching hurricanes or riverine floods.

(7) Approaches which provide policy makers with the information and decision-assisting tools which facilitate rationale and effective hazard management decision making.

General illustrations of approaches one through five are presented in the following figures:

CLASS I: METHODS FOR MINIMIZING THE PROBABILITY OF HAZARD OCCURRENCE (ABATEMENT) AND FOR PROTECTING HIGH RISK AREAS AND BUILDING SITES (PROTECTION)

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION
SUBTYPE ONE-ABATEMENT		
RIVERINE FLOOD	• REFOREST OR RESEED DENUDED AREAS • MECHANICAL LAND TREATMENT OF SLOPES, SUCH AS CONTOUR FARMING, TO MINIMIZE RUNOFF • PROTECT WATERSHEDS FROM FOREST AND GRASS FIRES • CONTROL OR ELIMINATE LARGE SCALE CLEAR-CUTTING OF FOREST LAND, AS IN REDWOOD PARK AREA • MANAGE WATERSHEDS TO MINIMIZE EROSION, (e.g. PREVENTING OVERGRAZING) • DESIGN AND CONSTRUCT NEW URBAN DEVELOPMENT SO AS TO PROVIDE TEMPORARY ON-SITE WATER RETENTION • CONSTRUCT CATCHMENT BASINS FOR DEBRIS AND SEDIMENT • CLEAR DEBRIS AND SEDIMENT FROM UPPER STREAMS • CREATE WATER HOLDING AREAS (i.e. SMALL LAKES) • RESTORE OR PRESERVE NATURAL DETENTION AREAS SUCH AS SLOUGHS, SWAMPS, SMALL LAKES	DECREASE IN RUNOFF COEFFICIENT FOR TREATED AREA DECREASE IN PEAK FLOW DOWN-STREAM
STORM SURGE	• SEED HURRICANES TO REDUCE PRESSURE DIFFERENTIAL (TECHNIQUES STILL IN RESEARCH STAGE) • MAINTAIN AND PRESERVE BARRIER ISLANDS AND COASTAL WETLANDS • PRESERVE, MAINTAIN, AND REPLACE COASTAL SAND DUNES	DECREASE IN STORM INTENSITY DECREASED WATER DEPTH AND/OR REDUCED WAVE ACTION
EARTHQUAKE	• RELIEVE EARTHSTRAIN RESULTING FROM TECTONIC MOVEMENT (TECHNIQUES STILL IN RESEARCH STAGE)	REDUCED POTENTIAL AND/OR SEVERITY OF EARTHQUAKE OCCURRENCE
SUBTYPE TWO - PROTECTION BY STRUCTURAL MEASURES - CONSTRUCTION OF ENGINEERING WORKS TO CONTROL OR PROTECT AGAINST HAZARD [CHANGE THE BASIC ACTION MECHANISM]		
RIVERINE FLOOD	• CONSTRUCT AND MAINTAIN LEVEES AND FLOODWALLS AS PHYSICAL BARRIERS • CONSTRUCT AND MAINTAIN CHANNEL IMPROVEMENTS TO INCREASE FLOW CAPACITY • CONSTRUCT DAMS AND RESERVOIRS TO STORE WATER AND RELEASE IT GRADUALLY • EMERGENCY FLOOD CONTROL (SEE CLASS V) • MINIMIZE FAILURES OF ENGINEERING WORKS WITH INSPECTION, REHABILITATION, AND REMOVAL FROM USE OF SUBSTANDARD STRUCTURES	ELIMINATION OF LOW RETURN PERIOD FLOODS (MAY HAVE INCREASED DAMAGE FOR RARE EVENTS) NO. OF STRUCTURES PROTECTED
STORM SURGE TSUNAMI	• CONSTRUCT AND MAINTAIN BREAKWATERS, LEVEES, AND FLOODWALLS AS PHYSICAL BARRIERS	
HEADWATER FLOOD	• LOCAL STREAM AND STORM DRAINAGE MANAGEMENT WITH DRAINS, STREET GUTTERS, CULVERTS, ETC.	DECREASE IN RUNOFF COEFFICIENT, INCREASE IN FLOW CAPACITY (MAY INCREASE DOWNSTREAM FLOW VOLUME)
EXPANSIVE SOILS	• COVER SITE WITH BLANKET OF NON-SWELLING SOIL • INSURE PROPER DRAINAGE	• COUNTERACTS SWELLING PRESSURES • REDUCES INFILTRATION
LANDSLIDES	• REFOREST AND RESEED DENUDED AREAS • PROTECT HILLSIDE AREAS FROM FOREST AND GRASS FIRES • MANAGE HILLSIDE AREAS TO MINIMIZE VEGETATION REMOVAL AND EROSION	• REDUCES, PREVENTS OR CONTROLS INFILTRATION AND EROSION

CLASS II: METHODS FOR STRUCTURAL STRENGTHENING AND/OR PROTECTION OF EXPOSED BUILDING

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION
RIVERINE FLOOD STORM SURGE TSUNAMI	• *FLOOD PROOF INDIVIDUAL STRUCTURE* *__TO MINIMIZE DAMAGE__* • ANCHORED SUPERSTRUCTURES • ANCHORED FUEL TANKS • DRAINS IN HEATING DUCTS • POSITIVE DRAINAGE FOR BASEMENT CEILINGS • SEPARATE CIRCUITS AND WATER PROOFING FOR FLOOD-ABLE ELECTRIC LINES • WATER RESISTANT FLOORING, CABINETRY, CARPETS • SLOPE ON GAS PIPING • MANUAL SEWER CUTOFF VALUES • BASEMENTS WITH BREAK AREAS TO ADMIT WATER PRIOR TO COLLAPSE OF WALLS • SPACE USAGE CONSISTENT WITH FLOOD HAZARD (i.e. SENSITIVE MACHINERY AND EQUIPMENT ON UPPER FLOORS) • WATER RESISTANT DOORS, PLYWOOD, INSULATION • DESIGN LOWER STRUCTURE TO WITHSTAND FLOODING • DESIGN STRUCTURE TO WITHSTAND SWIFT FLOW AND UPLIFT PRESSURES • FLOOD PROOF INDIVIDUAL STRUCTURES __TO KEEP WATER OUT__ • STRENGTHEN STRUCTURE TO SURVIVE WATER PRESSURE LOADS • PROVIDE FOR EMERGENCY OPERATION OF ELECTRICITY, WATER, AND SANITARY SERVICES • USE GLASS BLOCK FOR WINDOWS • CLOSE UN-NEEDED WALL OPENINGS • THOROSEAL COATING ON MASONRY TO REDUCE SEEPAGE • MASONRY CRACKS SEALED WITH HYDRAULIC CEMENT • SUMP PUMP AND DRAIN TO EJECT SEEPAGE • STEEL BULKHEADS FOR DOORWAYS AND OTHER OPENINGS (INSTALL ON WARNING)	DECREASE IN DEPTH-DAMAGE RELATION FOR MODIFIED BUILDING
WIND, TORNADO, HURRICANE	• ANCHOR ROOF SYSTEMS	• RESISTANCE OF ROOF SYSTEM TO UPLIFT PRESSURES
	• REQUIRE ROOFS TO HAVE HORIZONTAL SHEAR PANEL	• RESISTANCE OF ROOF SYSTEM TO UPLIFT PRESSURES
	• REQUIRE LATERAL FORCE BRACING OR SHEAR PANELS	• LATERAL RESISTANCE TO WIND PRESSURE
	• INCREASE WINDOW THICKNESS	• LATERAL RESISTANCE TO WIND PRESSURE
	• LIMIT WINDOW SIZE	• LATERAL FORCE REDUCTION
	• SHUTTER WINDOWS	• ELIMINATE EXPOSED AREA
TORNADO	• LIMIT WINDOW SIZE	• SURFACE AREA REDUCTION FOR MISSLE IMPACT
	• CONSTRUCT STRONG (OR STRENGTHENED) ROOM IN HOMES	• LATERAL RESISTANCE TO TORNADO WIND PRESSURE AND REDUCED MISSILE EXPOSURE AREA
EARTHQUAKE	• __STRUCTURAL MODIFICATIONS__ BASIC REDESIGN OR REINFORCEMENT OF: • STRUCTURAL FRAME • FOUNDATION • CONCRETE WALLS AND SLAB • FLOOR DIAPHRAGMS • PRECAST PANEL CONNECTIONS	• INCREASE RESISTANCE TO LATERAL EARTHQUAKE INDUCED FORCES
	• __NONSTRUCTURAL MODIFICATIONS__ INCLUDES PROPER ANCHORING, BRACING AND STRUCTURAL ISOLATION OF ELEMENTS: • MASONRY CORE • PRECAST PANELS • PLUMBING • HVAC • ELECTRICAL (INCL. LIGHTS) • ELEVATORS • WINDOW SYSTEMS • PARTITIONS • ACOUSTICAL CEILINGS • MISCELLANEOUS METALS	• DECREASE IN EXPECTED DAMAGE WHEN EXPOSED TO AN EARTHQUAKE EVENT
	• *__BUILDING MANAGEMENT__* • RELOCATING CERTAIN ESSENTIAL OPERATIONS INTO BUILDINGS OR PARTS OF BUILDINGS OF MORE RESISTANCE • DEVELOP PERSONNEL TRAINING PROGRAM WHICH WOULD INSURE THAT ESSENTIAL OPERATIONS WOULD CONTINUE TO FUNCTION IN THE EVENT OF AN EARTHQUAKE (E.G., TRAIN INDIVIDUALS TO OPERATE LOCAL POWER GENERATING EQUIPMENT IN HOSPITAL FACILITIES) • DEVELOP PROPER EVACUATION PROCEDURES WHICH WOULD INSURE THE SAFETY OF INDIVIDUALS LEAVING A BUILDING AFTER AN EARTHQUAKE (E.G., HIGH RISE BUILDINGS)	• MINIMIZE THE POTENTIAL FOR LOSS OF LIFE AND OPERATION

CLASS II: METHODS FOR STRUCTURAL STRENGTHENING AND/OR PROTECTION OF EXPOSED BUILDING

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION
EXPANSIVE SOILS	• STRUCTURAL REINFORCEMENT	• KEEPS STRESSES WITHIN ALLOWABLE RANGES
	• STRUCTURE/FOUNDATION ISOLATION • FOOTINGS OR CAISSONS PLACED BELOW SWELLING ZONE • AIR GAPS BETWEEN FOUNDATION, SLABS AND THE GROUND • PLACE FRANGIBLE MATERIAL BETWEEN POURED CONCRETE AND SOIL	• DECREASES OR ELIMINATES DAMAGE DUE TO SWELLING
	• CONTROL MOISTURE VARIABILITY • PLACE IMPERVIOUS APRON • PROPER DRAINAGE • PROTECT FORM LEAKS • RELOCATE TREES	• REDUCES SOIL MOISTURE VARIABILITY
	• ELIMINATE SWELLING • INJECT LIME SLURRIES • INCREASE DOWNWARD LOADS	• PREVENTS OR CONTROLS SWELLING
LANDSLIDES	• RELOCATE STRUCTURE • REMOVE FROM HAZARD AREA • SETBACK FROM HEAD OF SLOPE	• ELIMINATES OR DECREASES SLIDE POTENTIAL
	• MODIFY FOUNDATION • DEEP FOUNDATIONS AT TOP OF SLOPE • SHALLOW FOUNDATIONS AT BASE OF SLOPE	• DECREASES CRITICAL STRESSES
	• INSURE PROPER SURFACE DRAINAGE	• CONTROLS EROSION AND INFILTRATION
	• SLOPE STABILIZATION • FLATTENING OF SLOPE • PRESSURE BERMS AT TOE • INTERNAL DRAINS • ELECTROOSMOSIS • CONSOLIDATION • COMPACTION • GROUTING • ROCK BOLTS • PILES • RETAINING WALLS	• INCREASES FACTOR OF SAFETY

CLASS III: METHODS FOR MORE APPROPRIATELY PREPARING BUILDING SITES

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION
TORNADO AND HURRICANE	• CLEANUP DEBRIS	• REDUCTION IN POTENTIAL MISSILE DENSITY OF AREA
WIND	• CREATE WIND BREAKS (e.g., TREES, FENCES)	• REDUCTION IN WIND SPEED DUE TO INCREASED SURFACE ROUGHNESS
EARTHQUAKE	• STABILIZE AND COMPACT SOIL TO REDUCE RISK OF LIQUEFACTION AND DIFFERENTIAL SETTLEMENT	• INCREASED SOIL STRENGTH
EXPANSIVE SOILS	• PLACE BLANKET OF NON-SWELLING SOIL	• COUNTERACTS SWELLING PRESSURES
	• MODIFY EXISTING CLAY SOILS • INJECT LIME • CHEMICAL STABILIZATION	• REDUCES ABSORPTION AND CHEMICAL REACTIONS
	• COMPACTION TECHNIQUES • WETTER THAN OPTIMUM • ADD LIME • ADD GRANULAR MATERIAL • ADD VARIOUS SALTS	• REDUCES ABSORPTION • LOWERS PLASTICITY INDEX • INCREASES POROSITY • INCREASES ION CONCENTRATION
LANDSLIDES	• AVOID UNDERCUTTING TOE OF SLOPE	• MAINTAINS SLOPE STABILITY
	• INSURE PROPER DRAINAGE	• CONTROLS EROSION AND INFILTRATION
	• ANALYZE SLOPE STABILITY • SOIL BORINGS • SOIL TESTING • FACTOR OF SAFETY	• DETERMINE LANDSLIDE POTENTIAL
	• CONSTRUCT RETAINING WALLS	• REDUCES STRESSES ON SLIP PLANE
	• SLOPE STABILIZATION (SEE CLASS II)	• INCREASE FACTOR OF SAFETY

CLASS IV: METHODS FOR IDENTIFYING AND AVOIDING HAZARD PRONE AREAS THROUGH GEOPHYSICAL STUDIES AND LAND USE

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION

RIVERINE FLOOD
 	
STORM SURGE
 	
TSUNAMI
	• DELINEATE FLOODWAY, FLOODWAY FRINGE, FLASH FLOOD, OR OTHER HAZARD AREAS
	• RESTRICT USEAGE SO AS TO PREVENT INCREASED WATER DEPTH OR FLOW VELOCITIES
	• RESTRICT USEAGE SO AS TO MINIMIZE AND CONTROL RUN OFF
	• ALERT PEOPLE TO THE TRUE DEGREE OF HAZARD AT *THEIR PROPERTY*
	• PUBLIC PURCHASE OF FEE-INTERESTS OF FLOOD-PRONE LANDS TO RESTRICT LANDS TO OPEN-SPACE USE
	• PUBLIC ACQUISITION OF EASEMENTS USED TO PREVENT OR CONTROL DEVELOPMENT
	• TAX ADJUSTMENTS TO ENCOURAGE OPEN-SPACE USE AND CONTROL DEVELOPMENT
	• FLOOD-CONSCIOUS GOVERNMENTAL POLICIES IN EXTENSION OF PUBLIC SERVICES TO FLOOD-HAZARD AREAS
	• REGULATIONS TO PREVENT OBSTRUCTION OF FLOODWAYS
	  • ZONING
	  • SUBDIVISION
	  • ENCROACHMENT REGULATIONS
	  • REGULATIONS OF DIKES, LEVEES, DAMS, SEA WALLS, OR CHANNEL MODIFICATIONS
	• REQUIRE SELLS AND BROKERS DISCLOSE FLOOD HAZARDS IN REAL ESTATE TRANSACTION
	• RELOCATION OF EXISTING STRUCTURES
		REDUCTION IN NUMBER OF STRUCTURES SUBJECT TO FLOODING

WIND, HURRICANE AND TORNADO	• MICROZONATION TO ESTABLISH SEVERE WIND AREAS	• REDUCE DENSITY OF EXPOSED STRUCTURES

EARTHQUAKE	• REGIONAL INVESTIGATION OF THE SEISMIC OR EARTHQUAKE HISTORY OF THE AREA
	  • GEOLOGIC MAP OF REGIONAL AND/OR LOCAL FAULTS
	  • MAP(S) OF EARTHQUAKE EPICENTERS
	  • FAULT STRAIN AND/OR CREEP MAP
		IDENTIFICATION OF AREAS OF HIGH RISK AND REDUCE DENSITY OF EXPOSED STRUCTURES

	• LOCAL INVESTIGATION OF THE GEOLOGIC CONDITIONS AT OR NEAR THE SITE THAT MIGHT INDICATE RECENT FAULT OR SEISMIC ACTIVITY
	• SURFACE INVESTIGATION
	  • GEOLOGIC MAPPING
	  • STUDY OF AERIAL PHOTOGRAPHS
	  • REVIEW OF LOCAL GROUND WATER DATA
	• SUBSURFACE INVESTIGATION
	  • TRENCHING
	  • SOIL BORINGS
	  • GEOPHYSICAL SURVEYS
		IDENTIFICATION OF AREAS OF HIGH RISK AND REDUCE DENSITY OF EXPOSED STRUCTURES

	• LAND USE MANAGEMENT • LIMIT TYPES OF USE IN HIGH RISK AREAS (i.e., NO HOSPITALS IN AN ACTIVE FAULT ZONE)	REDUCE DENSITY OF EXPOSED STRUCTURES AND POPULATION

EXPANSIVE SOILS	• DETERMINE SWELLING POTENTIAL FROM SOIL INDEX PROPERTIES
	  • COLLOID CONTENT
	  • PLASTICITY INDEX
	  • SHRINKAGE LIMIT
	  • LIQUID LIMIT
	  • ACTIVITY
	  • GRAIN SIZE COMPOSITION
		• IDENTIFICATION OF HIGH RISK AREAS

	• MICROZONING TO ESTABLISH SWELLING PRONE AREAS	• IDENTIFICATION OF HIGH RISK AREAS
	• ALERT PEOPLE AS TO THE HAZARD TO THEIR PROPERTY	• ALLOWS OWNER TO TAKE ACTION

LANDSLIDES	• REGIONAL MAPPING AND INVESTIGATIONS
	  • TOPOGRAPHY
	  • PRECIPITATION
	  • GEOLOGY
		• IDENTIFY POTENTIAL SLIDE AREAS

	• LOCAL INVESTIGATIONS
	  • SOIL BORINGS
	  • GEOPHYSICAL SURVEYS
	  • ON-SITE INSPECTIONS
		• IDENTIFY POTENTIAL SLIDE AREAS

	• DETERMINE SLIDE POTENTIAL FROM SOIL INVESTIGATIONS
	  • SLOPE GEOMETRY
	  • SOIL OR ROCK STRENGTH
	  • WATER TABLE
	  • DENSITIES
	  • SEEPAGE FORCES
	  • ANALYSIS
		• IDENTIFY FACTOR OF SAFETY AGAINST *SLIDING*

	• MICROZONATION TO ESTABLISH SLIDE PRONE AREAS	• IDENTIFICATION OF HIGH RISK AREAS
	• LIMIT USE IN HIGH RISK AREAS SUBJECT TO CATASTROPHIC SLIDING	• REDUCE EXPOSURE OF PEOPLE AND STRUCUTRES
	• ALERT PEOPLE AS TO THE HAZARD AT THEIR PROPERTY	• ALLOWS OWNER TO TAKE ACTION

CLASS V: RELIEF AND REHABILITATION - PROVIDE PUBLIC MONEY TO ASSIST VICTIMS IN RECOVERING FROM THEIR LOSSES

HAZARD	SPECIFIC ACTION OR EXAMPLE	PURPOSE OF MITIGATION
RIVERINE FLOOD STORM SURGE TSUNAMI EARTHQUAKE EXPANSIVE SOILS LANDSLIDES TORNADO HURRICANE SEVERE WIND	• INSURANCE • SPREADS THE LOSS • PROVIDES MONIES FOR REHABILITATION, ANOTHER FORM OF DISASTER RELIEF (BECAUSE OF HEAVY SUBSIDY) • REQUIRED IN DESIGNATED FLOOD AREAS FOR FEDERAL ASSISTANCE • COUPLE WITH LAND USE CONTROLS	REDUCES INDIVIDUAL LOSSES REDISTRIBUTES ECONOMIC LOSS
	• LOANS • REDUCE RATE ON EXISTING FEDERAL LOANS • REDUCED RATE ON THE RECONSTRUCTION LOANS • PRESENTLY REQUIRES FLOOD INSURANCE (FLOOD HAZARDS ONLY) • PRESENTLY REQUIRES FLOOD DAMAGE MITIGATION PROGRAM (FLOOD HAZARDS ONLY)	FORCING MECHANISM TO COMPLY WITH LOCAL REGULATIONS
	• GRANTS • TO INDIVIDUALS • TO LOCAL GOVERNMENTAL AGENCIES - PRESENTLY REQUIRES LOCAL FLOOD DAMAGE MITIGATION PROGRAM - (FLOOD HAZARDS ONLY) • TO STATES FOR PREPARING PLANS FOR DISASTER PREPAREDNESS AND PREVENTION	INCENTIVE TO INCLUDE HAZARD MITIGATION IN PLANNING PROCESS
	• FEEDING AND SHELTERING OF VICTIMS • FOOD STAMPS • FREE TEMPORARY HOUSING • FREE CLEAN UP SUPPLIES • FREE REPAIR AND RECONSTRUCTION OF PUBLIC STRUCTURES	ELIMINATE DISASTER HARDSHIP AND AID IN SPEEDUP OF RECOVERY
	• DISASTER UNEMPLOYMENT INSURANCE	
	• TAX DEDUCTIONS	ASSIST IN RECOVERY THROUGH TAX RELIEF
	• TECHNICAL ASSISTANCE AND ADVICE TO STATES AND LOCAL GOVERNMENTS IN: • PERFORMANCE OF ESSENTIAL COMMUNITY SERVICES • WARNING OF FURTHER RISKS AND HAZARDS • PUBLIC INFORMATION AND ASSISTANCE IN HEALTH MEASURES • PUBLIC INFORMATION AND ASSISTANCE IN SAFETY MEASURES • MANAGEMENT AND CONTROL • REDUCTION OF IMMEDIATE THREATS TO PUBLIC HEALTH AND SAFETY • DISTRIBUTION OF MEDICINE, FOOD AND OTHER CONSUMABLES	ASSIST IN ACHIEVING EFFECTIVE PLANNING AND PUBLIC AWARENESS OF HAZARD POTENTIAL

Chapter Three

METHODS EMPLOYED IN STUDY

Introduction and Summary

In general, risk analysis consists of a set of operations aimed at identifying: (a) the probability that a particular event, set of events, and/or event intensities will occur over some specified time frame, (b) the area and/or populations that will experience or be exposed to the event (e.g., the population at risk), (c) the vulnerability of the area and/or exposed populations to effects associated with the event, and (d) the consequences which will occur if the population at risk is exposed to some expected series of intensities of the event over some specified time frame. The outputs of a risk analysis may take the form of probabilistically-derived, annualized estimates of the consequences which will arise from exposure of a specified population-at-risk to the event or hazard. In respect to the analysis of risks associated with the exposure of people and property to natural hazards, risk analysis is defined to include the following:

(1) Identification and description of the characteristics, geographic distribution, and potential effects of hazardous natural events (hazard analysis);

(2) Assessment of the vulnerability of the several classes of buildings, building contents and building occupants to each hazard (vulnerability analysis);

(3) Identification and measurement of the major primary, secondary and higher order effects expected to be associated with the exposure, by major geographic areas, of building contents, buildings, and their occupants to these same hazardous natural events (loss analysis);

(4) Identification of the costs and characteristics of the major types of technologies appropriate for mitigating the effects induced by exposure of buildings and their occupants to hazardous natural events (technology analysis);

(5) Estimation of the economic costs and other effects associated with use of selected technologies to mitigate the effects of natural hazard exposures (cost analysis);

(6) Identification of risk references and comparison of hazard exposure losses and mitigation costs against those references (risk reference analysis).

The first step in the performance of a natural-hazards-oriented risk analysis may be referred to as the risk determination phase. Natural hazard risks are those impacts or effects of natural hazard exposures which may be viewed as undesirable in either the short or long term, even though such effects may sometimes be viewed by the public as "normal". Such impacts, effects, or events, tend to cluster into two groupings.

The first group consists of low level geologic events which create minor damage on a continuing basis, such as expansive soils. The second grouping contains risks which are characterized by major undesired consequences resulting from natural events but which happen suddenly, such as earthquakes and tornadoes. The consequences of these events may be felt either immediately or in the long term. The risk determination procedures employed here were necessary to acquire a comprehensive insight into the effects of calamities or catastrophes caused by nature upon society. Generally, the effects are measured in terms of pure economic dollar loss and numbers of people killed or injured. It is important, however, to consider effects on social disruption such as unemployment and homelessness as well as the general impact upon the quality of life. These aspects make the risk determination much more complicated. Further, these effects need to be given different weights in the analysis than have been done before.

This chapter will provide an overview of the general approach to risk determination for natural hazards, as well as a summary of the methodology or procedure as employed for each of the nine natural hazards considered here.

This chapter addresses each of the several classes of methods which were used in the study, including the following: (a) risk determination methods used in estimating annual expected losses from natural hazard exposures in specific sites or areas, (b) methods for determining the loss reductions achievable through use of specific mitigations, (c) methods for determining the costs and cost-feasibility of specific mitigations, and (d) methods for determining future population, building, and building-mix loadings in specific sites or areas.

General Approach to Hazard Risk Determination

A natural event generally is of concern when it produces effects upon human beings and/or their property. Thus, concentration on the physical aspects of a natural event is important to development of an understanding of the phenomenon and its impact on buildings and people. Specifically, natural hazard related damages are a function of the physical hazard (e.g., flooding, area inundated, depth of water, velocity, debris content, etc.) and the nature of the area impacted (population, land use, and investment in buildings). Both the physical hazard and the use made of the land in proximity to the hazard may change significantly over time. Thus, it is necessary to understand the nature of the existing socio-economic conditions in a hazard area in order to determine the types and magnitudes of damages which may be expected now or in the future. The risk determination procedure employed in risk analysis portion of this technology assessment is presented graphically in Figure 3-1.

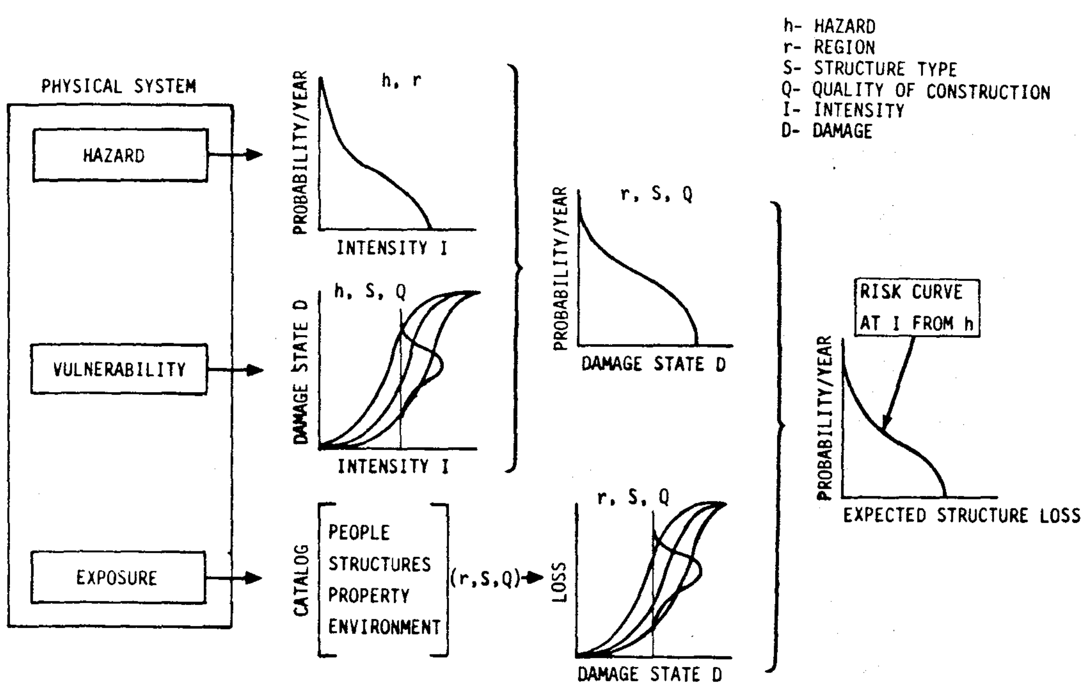


Figure 3-1. Generalized Natural Hazard Risk Determination Procedure

As shown in the risk determination model, the evaluation of a physical system consists of an assessment of the probability of the occurrence of a natural event at its various intensity levels. Intensity in this context relates to such elements as wind velocities, water depth, ground shaking, or ground movement. Since natural events are occurring all of the time, they generally are of concern only when their intensity levels are such that they cause significant damage or harm to individuals or a community at large. Thus, the intensity is important as it relates to the quality of structures or buildings exposed. Structures or buildings vary in their degree of vulnerability to the intensity of a hazard as a function of their design, materials, or general quality of construction. As an element in the risk determination process for naturally occurring events, it was necessary to classify structures by type and use. The classification by structure type is related to the type of construction (considering both design and materials) generally associated with the specific structure type. For example, in California home construction generally is wood frame, slab floor, stucco plaster exterior, and shake roof, with large glass window areas. Commercial buildings tend to be either of similar construction or of tilt-up concrete slab type construction. These factors are important in evaluating the vulnerability of structures to such natural events as flooding, wind storms, and earth movements. In California, therefore, where basements are not common, the impact of low-depth flooding is not as significant as in areas of the midwest or east where basements are common practice. However, California-type home construction may be more vulnerable to high wind velocities.

Intensity of the hazard event and quality of construction are important only to the extent that the buildings or structures of concern are exposed to the event. Thus, exposure (i.e., land use density) is an important factor in the risk determination process. From reviewing the generalized risk determination procedure [Figure 3-1] one can see that the integration of the probabilities of varying intensities from natural events with the exposure of various types of structures and buildings, of various qualities of construction can produce an expected loss of structure as a function of the probability of damageability. Thus, the risk determination procedure used in this study involves the development of a probabilistic hazard model for each of the nine natural hazards and a forecasting of the location of various structure types and quality of construction by area where hazards of a given type are expected to occur.

This procedure involves the development of estimates of hazard intensity-damage functions for major types of land use and requires the collection of data pertaining to the relationships between hazard intensities and damageability of structures in terms of economic loss for the various structural classifications. Risk of damage coefficients must be developed for local areas based upon the economic value of structures of buildings exposed to specific hazard types. This method deals mainly with direct damages to buildings or structures. For certain hazards (e.g., earthquake, tornado) indirect damages or losses also are an important aspect of risk determination. It was necessary on the basis of exposed population to forecast the mix of building types, their contents, and their function in the community. This information when integrated into the risk determination model provides a basis for determining the expected losses of contents contained in buildings, the losses in income associated with buildings which contribute to the economic basis of the community, and losses associated with the dislocation of suppliers, which result in an increased transportation-distribution cost. From this data, it is possible to forecast expected losses of life, unemployment, and homelessness in affected areas.

The risk determination process is, therefore, all inclusive in that it allows for the quantification of relevant economic and social consequences.

Exposure Vulnerability Estimation

As noted above, this study is concerned with the extent of damage to buildings, their contents, and various other socio-economic impacts which may flow from the basic losses of buildings due to expected various natural events. Methodologically, these expected damages or losses are derived from the value in dollars of buildings and contents at risk multiplied by the probability of various levels of loss from a given type of occurrence. Two sets of information must be developed. One set results in the assignment of the annual probability of occurrence for each of the natural hazards studied in this project. The other set of data provides the dollar value of the items at risk.

This approach does not diminish uncertainty about the future but rather points to the long range decision rule: In the long run, the value of what will be lost due to the occurrence of natural events is the value of items at risk (exposure) multiplied by the various probabilities of levels of loss (vulnerability). This notion is not intended to define the precise consequences of any specific event, but to provide policy makers with an understanding of the relationship between natural events and expected losses associated with the events over an extended period of time.

Once the value of the items subject to a level of risk is known, it is possible to derive the expected annual loss by multiplying the amount at risk by the probability of loss of some portion of that amount, summed over all contingencies. This series of probabilities is illustrated in the form of an event tree, shown in Figure 3-2 .

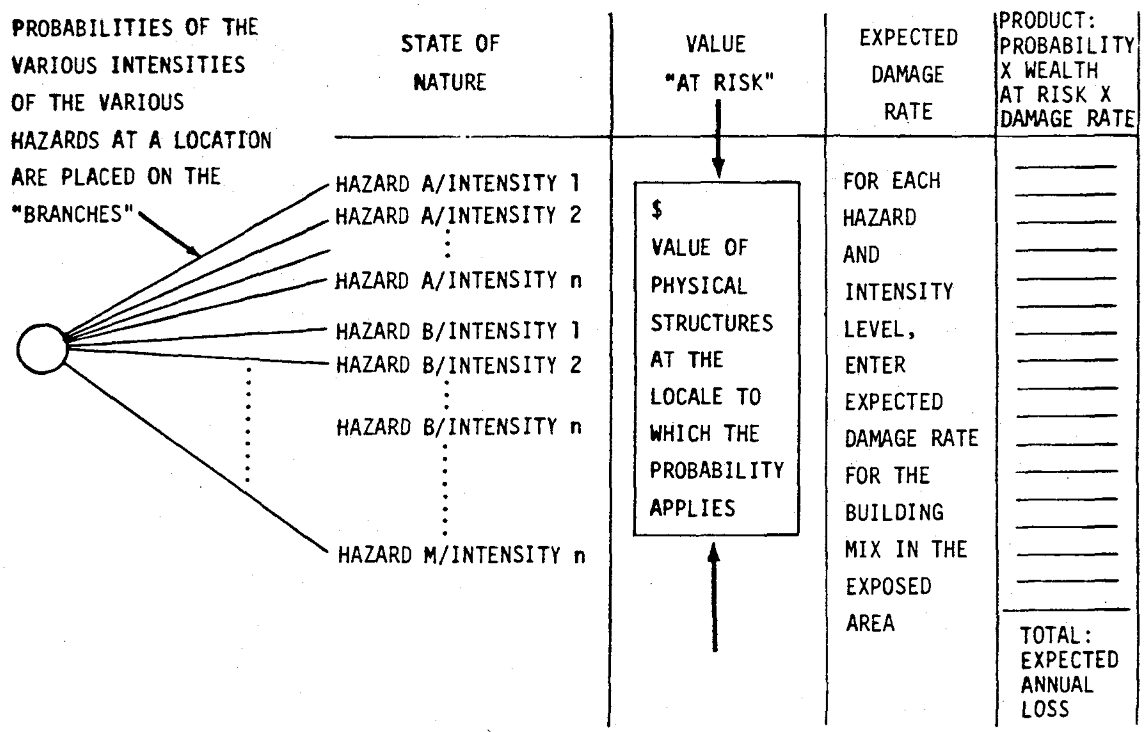


Figure 3-2. Event Tree for Deriving Expected Loss from Probabilities of Extreme Natural Events

The probabilities placed on the branches of the event tree represent the likelihood of a certain natural event occurring with a specific intensity. This means that there is a set of contingencies and intensities of a hazard - each of which is a branch of the event tree and each of which has an annual probability of occurrence.

The sum of the elements of the right hand column represents the annual expected dollar loss for a specific location from a natural hazard. Again, it should be noted that this expected value does not represent loss from any specific event, but is the mean value of loss over an extended period based on the probabilities assigned to the branches of the event tree.

Many of the probabilities of annual states of nature are available from the historical record; however, the determination of the dollar value of items at risk is a more subtle economic problem. Care must be taken to account for the relevant dimensions of value. At the same time, double counting must be avoided. Finally, once the dimensions of the factors of risk have been catalogued, they must be given an accurate dollar valuation. Such valuations are obvious in some instances and elusive in others.

As noted, the intensity of the hazard will result in certain losses in buildings and their contents, losses in income and an increase in supplier transportation costs. These four types of losses are referred to as "Economic" losses. "Social" losses are identified in this study as life loss, homelessness, and unemployment. Both sets of losses are derived from the expected losses in building wealth. Specifically, the determination of the impacts progress from the physical phenomena to aggregate economic and social costs. The order of computation for assessing the hazards effects or impacts is presented in Figure 3-3.

Building wealth losses are determined as a function of damage rates, or the proportion of replacement value needed for repair of the buildings. The damage rates associated with a hazard intensity are applied to buildings of various types and to building contents within particular sections of the local economy.

Expected income losses are estimated through the use of a regional multi-sector model of income determination where eleven sectors are considered (i.e., farming, construction, manufacturing), and the regions are either counties or states. These estimates are computed by including the relationship between damage rate and the amount of down time of productive capacity

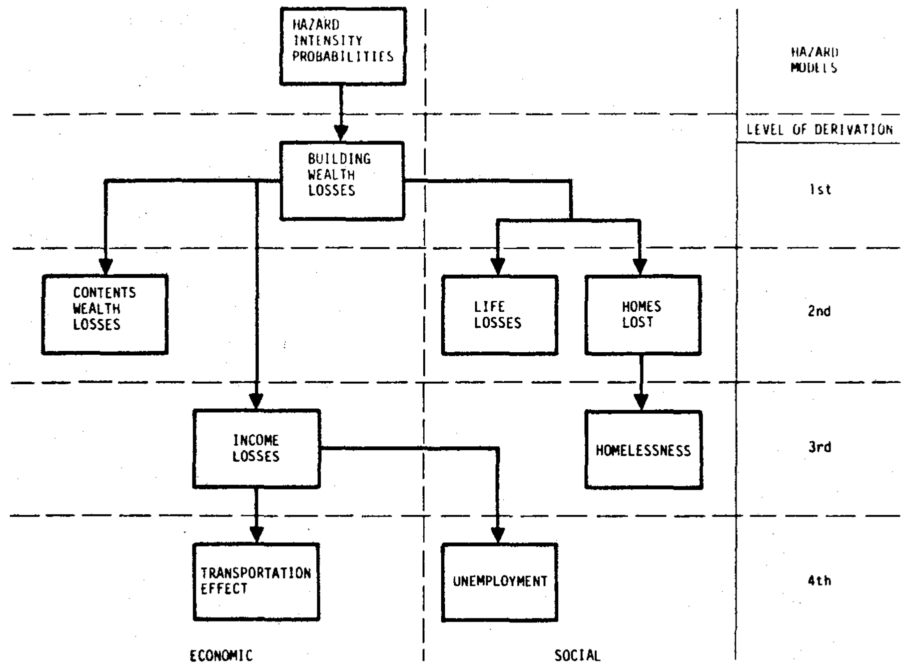


Figure 3-3. Comprehensive Risk Determination Methodology by Order of Computation

within those buildings. This allows estimation of loss of production due to the inactivity of productive capital.

A third expected dollar loss investigated is the loss experienced by a purchaser who, even though not sustaining direct damages, nonetheless experiences increased transportation costs for a product no longer available from a supplier suffering damage in the hazard exposure area.

In addition to losses in economic terms, some of the effects of natural hazards are described in the form of non-economic relationships. Specifically, the level of "homelessness" is estimated in terms of estimated person days of homelessness resulting from a specific hazard. Another such aspect is the projected unemployment associated with an event. This is quantifiable in economic terms but is not included in the economic loss calculations since production loss computations already account for this part of wealth loss. In fact, adding expected unemployment to the loss computations would be an example of double accounting. Nevertheless, this dimension of loss is identified separately. In addition to the specific social and economic losses identified, expected levels of life loss are predicted. They are quantified as part of the economic calculations and are presented in terms of numbers of lives lost as a function of a given natural hazard.

A detailed presentation of the economic exposure-vulnerability model and the assessment procedure utilized in the various social and wealth impact studies is contained in: "Natural Hazards: Socio-Economic Assessment Model", by Hirschberg, et.al, [1978].

Methods for Determining Present and Future Exposure to Hazards

Critical to the performance of a natural hazards risk analysis is the definition of the size and characteristics of the human and structural populations which are, or will in the future be, exposed to a specific hazard at a specific intensity level.

For all hazards except tsunami and riverine flooding, the quantitative identification and categorization of populations at risk of exposure to natural hazards in 1970, 2000, and intervening years was calculated exclusively from a county aggregated data base. The components of the data base are shown in Figure 3-4.

General County Data Base

In general, census data provided the basis for determining 1970 counts, by county of population, residential structure (by type) and value of residential property. 1970 national values for publicly-owned, commercial, and industrial buildings were derived from data published by the National Bureau of Economic Analysis (NBEA); and were allocated to the several commercial-industrial categories utilized in the study (farming; mining; construction; manufacturing; trans-utility; finance, insurance, real estate; and services) in proportion to their corporate capital consumption allowances by year as reported by NBEA. The national value of publicly-owned, commercial, and industrial structures was allocated to individual counties on the basis of census-reported county income, by sector of the economy.

Projections of these values to 2000 were based on use of regression equations derived from national population and income projections developed by U.S. Water

TYPE OF DATA	DATA AGGREGATED TO LEVEL OF:	DATE DATA TAKEN	NUMBER OF DATA POINTS	SOURCE
GENERAL COUNTY DATA				
County population	County	1970	3,132	[Newspaper Enterprise Assoc., 1974]
County area	County	1970	3,132	" "
County name	County	1970	3,132	[National Bureau of Standards 1974]
County latitude and longitude	County	1970	3,132	[Dept. of Interior, 1970]
County coastal flag (whether on an ocean coast or not)	County	1970	3,132	" "
Name of SMSA County is part of	County	1970	3,132	[U.S. Water Resources Council, 1971]
HOUSING CHARACTERISTICS DATA				
Percent of housing units with basements	State NSMSA SMSA	1970	298*	[U.S. Bureau of Census, 1972]
Percent of housing units with cement slab foundation	State NSMSA SMSA	1970	298	" "
Percent of housing units built before 1940	State NSMSA SMSA	1970	298	" "
Percent of housing units that are mobile homes	State NSMSA SMSA	1970	298	" "
Percent of housing units in structures with 4 or more stories	State NSMSA SMSA	1970	298	" "
Percent of housing units in structures with 5 or more stories	State NSMSA SMSA	1970	298	" "
Average number of persons per housing units	State NSMSA SMSA	1970	298	" "
ECONOMIC DATA				
Locally assessed real property values	County	1971	3,132	[U.S. Bureau of Census, 1972]
Assessment-Sales price ratios	State	1971	2,002	" "
Total personnel income percapita	NSMSA - WRCS, and SMSA	(1980)*	452	[U.S. Water Resources Council, 1974]
Total agricultural income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total mining income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total construction income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total manufacturing income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total wholesale-retail income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total financial insurance, real estate income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total service industry income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total federal government income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Total state and local government income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
Percent of national average of total local income percapita	NSMSA - WRCS, and SMSA	(1980)	452	" "
GROWTH PROJECTIONS				
Intercept of population projection***	NSMSA - WRCS, and SMSA	(1970-2000)	452	[U.S.Water Resources Council, 1974]
Slope of population projection***	NSMSA - WRCS, and SMSA	(1970-2000)	452	" "
Intercept of income/percapita projection***	NSMSA - WRCS, and SMSA	(1970-2000)	452	" "
Slope of income/percapita projection***	NSMSA - WRCS, and SMSA	(1970-2000)	452	" "

*247 SMSA where used in the 1970 census and 51 states, District of Columbia the 51st.

**Projected data.

***Computed linear least square fit of projected data from 1970-2020.

Figure 3-4. County Data Base and Sources

Water Resources Council [OBERS], 1974. These regression equations were input to the county data base and used to develop county-level projections of 1970-2000 population, housing, and income levels. Projections of non-residential building values then were derived from the income projections, by sector of the economy. Projected values of both housing and other structural wealth were calculated using appropriate building survival curves and depreciation rates.

Values of Property in Tsunami Zones

For the purposes of estimating present and future losses from tsunami, building values per square mile of port facility also were needed. These were calculated by determining average values of industrial property per square mile in major U.S. cities [Manvel, 1968] and the ratio of industrial acreage to the total land area in such places. The national values resulting from these calculations were regionalized on the basis of relative level of per capita income in each exposed county to the national average per capita income. Projections of these county values were based on use of national income and growth rates.

Population Levels and Building Values in Flood-Prone Areas

All study estimates of population at risk of exposure to riverine flooding were derived from a national-scope computer model which was developed for this study. Among the primary inputs to the model were the 1967 findings by the U.S. Corps of Engineers that 5539 cities of various sizes were subject to periodic flooding [See Table 3-1] and that 2037 U.S. communities had been equipped with area flood protection structures and facilities [Lee, Chrostowski, and Eguchi, 1976]. Based on U.S. regional population loadings and city sizes, 5539 communities in the size ranges identified by the Corps therefore were assigned to the computer-modeled 10 U.S. regions. These regions were identified on the basis of physiographic, climatologic, and demographic parameters.

City Size	Number of Places with Flood Problems (Incorporated Municipalities)
Greater than 100,000	140
50,000 - 100,000	204
25,000 - 50,000	390
10,000 - 25,000	903
5,000 - 10,000	992
2,500 - 5,000	1,098
1,000 - 2,500	1,812
TOTAL	5,539

Source: U.S. Army Corps of Engineers, 1967

Table 3-1. Number of Urban Places with Flood Problems

Utilizing data developed by other authors [Friedman and Roy, 1972; Schneider and Goddard, 1974], plots were constructed to show the percentage of dwelling units estimated to be located in various flood zones of the modeled cities [See Figures 3-5 and 3-6]. These data then were converted into tabular form to show the fraction of dwelling units in various flood zones within urban communities. As shown in Table 3-2, the number of dwelling units in Zone F (all areas outside the 100 year flood plain) is equal to the sum of the dwellings in Zone A through E (zones within the 100 year flood plain). This apportionment was not intentional, but was what the data yielded. It results in greater exposure of the national population to a type F flood than that depicted in previous models. Following application of these procedures, census reported population levels per dwelling unit in each of the U.S. regions identified in the study then were determined. These were utilized to build population estimates for study cities used in the riverine flood model.

HAZARD ZONE	RETURN PERIOD OF FLOOD	FRACTION OF DWELLINGS ON 100 YR. F.P.*
A	2-5 years	.135
B	5-10 years	.150
C	10-25 years	.200
D	25-50 years	.245
E	50-100 years	.270
		(A–E: $\Sigma = 1.0$)
F	More than 100 years	1.000

*There are as many dwelling in zone F as in Zone A to E inclusive

Table 3-2. Distribution of Dwelling Units by Flood Hazard Zone

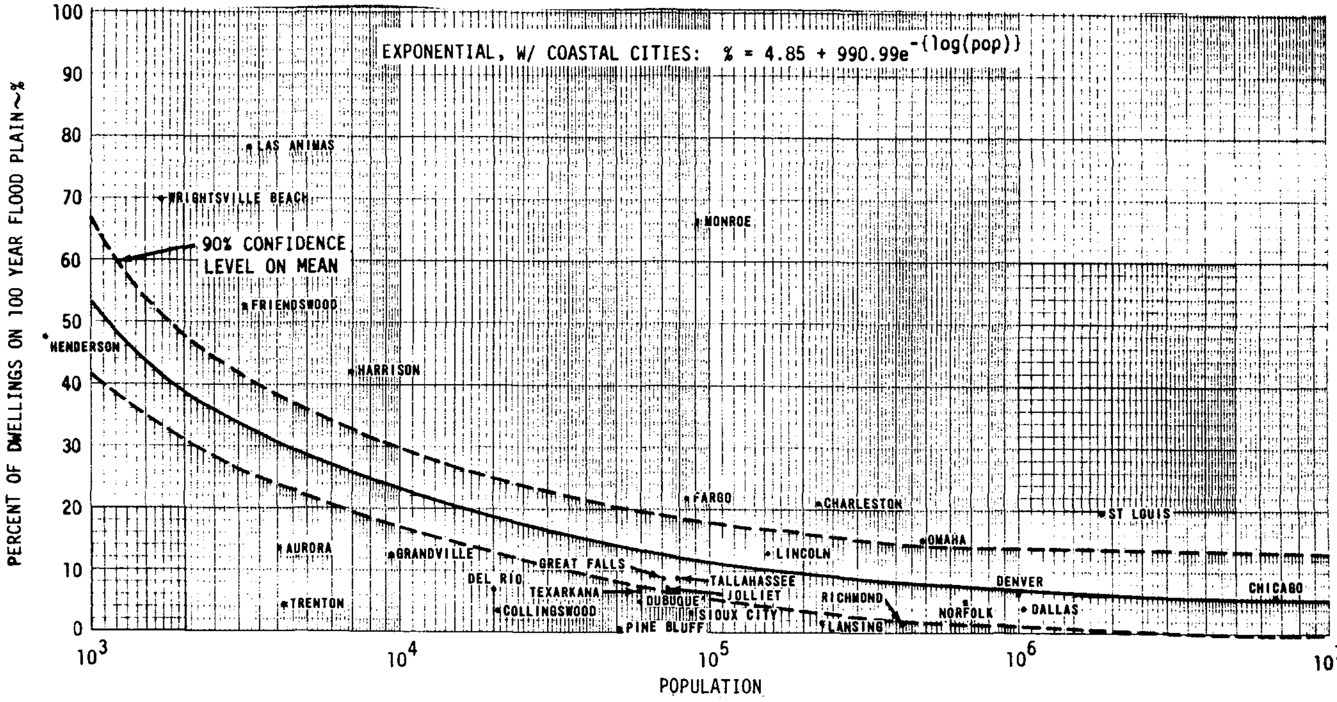


Figure 3-5. Percent of Dwellings on 100-year Flood Plain - CENTRAL AND COASTAL PLAINS

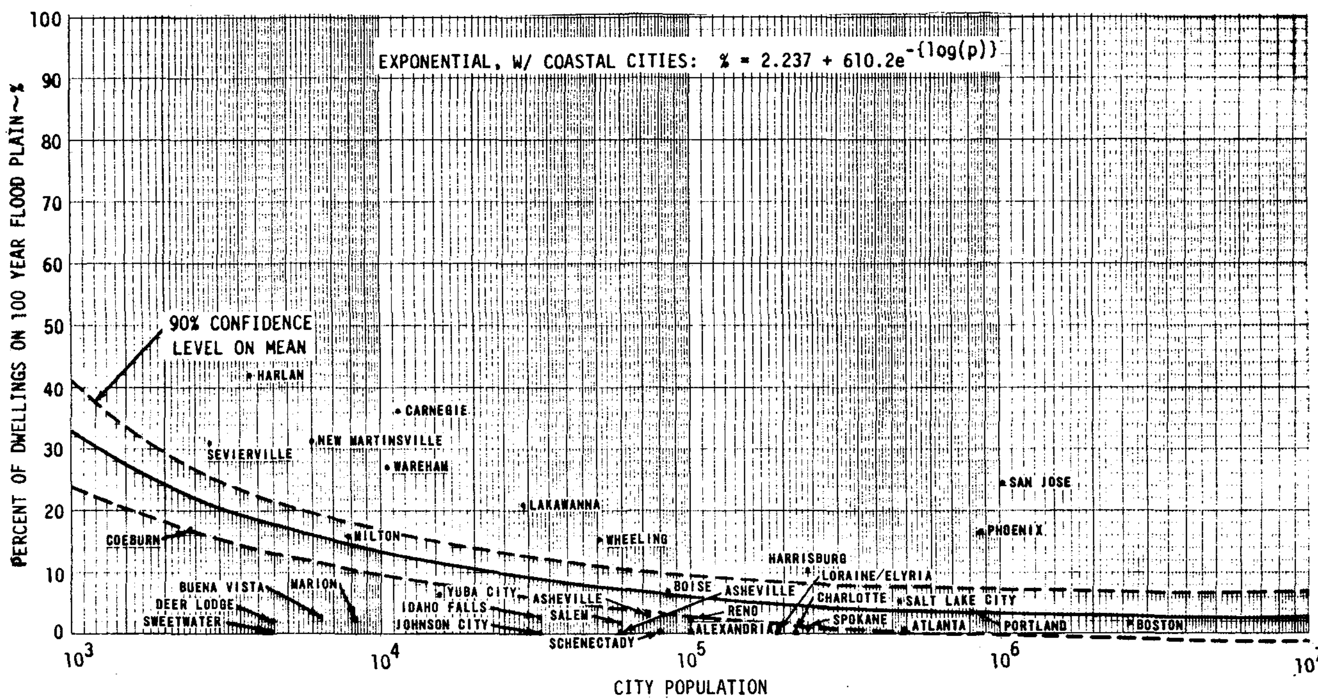


Figure 3-6. Percent of Dwellings on 100-year Flood Plain - WESTERN AND EASTERN HIGHLANDS

National data on the numbers and value of commercial/industrial and governmental buildings were allocated to the ten study regions of the United States, and within each region further apportioned to the study cities. Once the number of commercial/industrial and governmental properties in each city was established, they were apportioned to the several flood zones of the city in the same proportion as residential structures. Data from the U.S. Bureau of the Census were utilized to determine the median value of owner-occupied housing units in study regions. Utilizing data developed by Musgrave [1974], these values were modified to remove the value of land. To account for varying values of property by flood hazard zone, a scale factor derived from the Friedman model [Friedman and Bocacchino, 1972] was applied to the data. The result of these procedures was assignment of a value of $184,000 to each commercial/industrial and governmental property within flood modeled cities, and the residential property values by city size and flood hazard zone which are depicted in Table 3-3.

REGION	CITY-SIZE CATEGORY	FLOOD HAZARD ZONE A	B	C-F
		REPLACEMENT VALUE IN 1000 (1970 DOLLARS)		
1-2	A	11	13	15
	B	13	15	17
	C	15	18	20
	D	15	17	20
	E	13	16	18
	F	13	16	18
	G	10	12	14
3-4	A	12	14	16
	B	13	16	18
	C	13	16	18
	D	13	16	18
	E	11	13	15
	F	11	13	15
	G	8	10	11
5-8	A	10	12	14
	B	10	12	14
	C	11	12	14
	D	11	12	14
	E	9	11	12
	F	9	11	12
	G	7	8	9
9-10	A	15	18	20
	B	16	18	21
	C	15	18	21
	D	14	17	19
	E	12	14	16
	F	12	14	16
	G	9	11	13

Table 3-3. Replacement Value of Dwellings by Region, City Size, and Flood Hazard Zone

Estimates of Building Contents Value

Estimates of the value of building contents were developed for each type of building categorized in the study. The value of the contents of residential buildings was derived from Shavell [1970]. The value of the contents of farm, manufacturing, wholesale trade, and retail trade buildings were derived from national estimates developed by Loftus [1972]. The value of the contents of all other types of buildings examined in the study were derived from national estimates by the National Bureau of Economic Analysis [NBEA, 1974]. For the latter, appropriate allocations to the various classes of buildings used in this study were made on the basis of a five-year moving average estimate of the capital consumption allowances for each economic sector. In all cases, projections of building contents value were calculated using appropriate content service lives, survival curves, and depreciation rates. Estimates of building content value were made from the Institutional Investors Study Report of the Securities and Exchange Commission [National Bureau of Economics and Research, 1971].

To project the contents value at risk in future years, relationships of the following form were used:

$$V = \alpha e^{\beta(y-1900)}$$

where:

- V = value of contents in year y
- y = year of estimation
- α = constant
- β = coefficient of exponent (rate of growth)

Based on the use of these methods, the value of building contents is projected to increase at a faster rate than the value of buildings. As a result, by the year 2000, total U.S. building contents value is estimated to be 6.3 trillion dollars and the total U.S. structure value is estimated to be 4.9 trillion dollars. Thus, by the year 2000, the value of what a building contains will exceed the value of the structure in which it is housed. This circumstance results, of course, from the high projected increases in per capita income, and from the linkage between per capita income and consumer-business investment in building contents and consumer goods.

Risk Determination Methods, By Type of Hazard

Presented below is a brief discussion of the methods used in completing the risk determination procedure for each hazard. As noted above, these procedures were intended to reveal: (a) the distribution and occurrence of natural hazards within the United States, by various levels of intensity; (b) the population at risk of exposure to those hazards; (c) the vulnerability of the several populations to the exposures; (d) the annual losses expected to be associated with those exposures.

Earth Hazards

Three earth hazards were examined in this study: earthquake, expansive soils, and landslide. Since slightly different procedures were used in the examination of each, the methods specific to each are presented below. Detailed discussion of the models and study methods is contained in "Natural Hazards: Earthquake, Landslide and Expansive Soils Loss Models" by Wiggins, Slosson, and Krohn. J.H. Wiggins Company, Redondo Beach, California, 1978.

Earthquake

Although many analysts have examined the general subject of earthquake hazards in the United States, most have only viewed the subject in terms of the probability of earthquake occurrence in magnitude. In contrast, this study not only examines these questions, but also gives consideration to such related subjects as the vulnerability of buildings to ground movements induced by earthquakes; the value of property exposed to this hazard, annual losses expected to arise from such exposures; and methods which might be utilized to mitigate the consequences of earthquake exposures. The procedures utilized in the study are summarized, in general, in Figure 3-7.

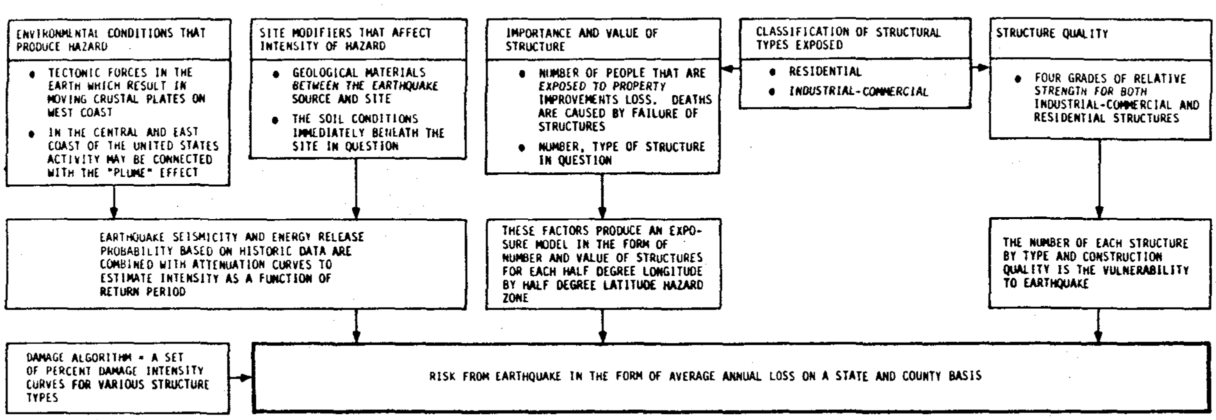
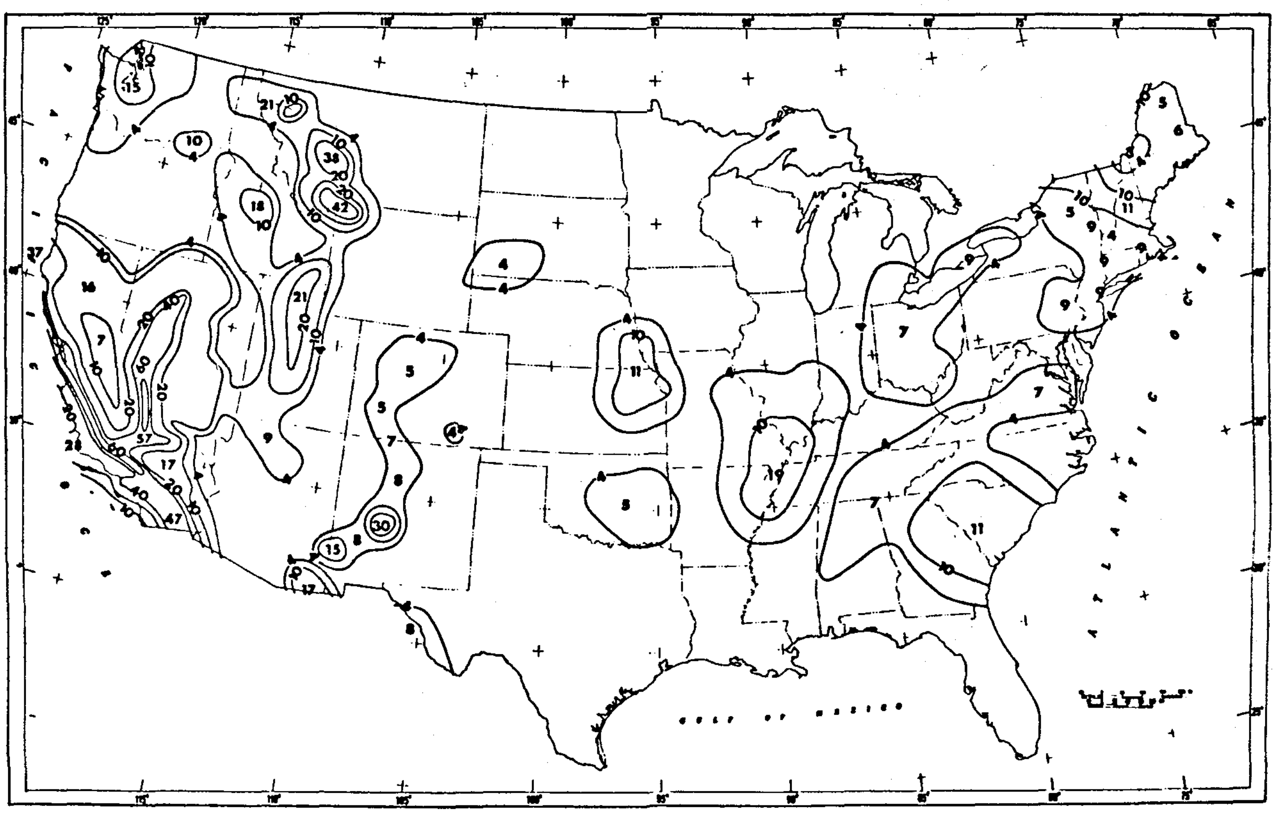


Figure 3-7. Earthquake Risk Determination Procedure

The MMI scale is defined in terms of damage potential. The term "damage potential" is used as a reminder that actual damage may occur only when structures are exposed to the hazard. That is, where there are no structures, there can be no structural damage, regardless of the intensity of the earthquake hazard.

Just as one may consider the frequency of occurrence of earthquakes within a region as a function of Richter magnitude, so may one consider the frequency of occurrence of earthquake ground shaking at a site, as a function of intensity. The frequency of ground shaking, by site, as a function of intensity, constitutes the basic hazard model for earthquakes. Algermissen and Perkins [1976] have developed a ground shaking acceleration map for the United States [Figure 3-8].



PRELIMINARY MAP OF HORIZONTAL ACCELERATION (EXPRESSED AS PERCENT OF GRAVITY) IN ROCK WITH 90 PERCENT PROBABILITY OF NOT BEING EXCEEDED IN 50 YEARS

The Maximum Acceleration Within The 60-percent Contour Along The San Andreas And Garlock Faults in California is 80 Percent of g. (Using The Attenuation Curves of Schnabel And Seed, 1973)

Source: U.S Geological Survey Open-File Report 74-416, 1976

Figure 3-8. Seismic Risk Zone Map Developed by Algermissen and Perkins

However, in order to estimate building losses as a function of intensity it was necessary to develop a Modified Mercalli Intensity Map of the United States [Figures 3-9, 3-10, 3-11]. Ground shaking, in terms of MMI can then be estimated on a half-degree longitude by half-degree latitude grid system when overlaid on the United States map.

Annualized estimates of structural damage caused by such ground shaking each year can be estimated from information showing the damage which will be sustained by the various types of structures exposed to the earthquake intensity range predicted as relevant to a particular geographical locale. The Modified Mercalli Intensity scale which describes intensity in terms of local effects of earthquakes, is well understood, and is most closely related to damage.

The lower limit of the intensity scale which may produce measurable damage was selected to be MMI=6. Damage at levels below an MMI=6 were considered slight and difficult to define. The upper limit of the intensity scale was set at MMI=12. At this severe intensity, damage to buildings is expected to be total.

Since force increases exponentially with intensity, it is reasonable to expect that damage will also increase exponentially with intensity. The damage algorithm is then a direct relationship between the amount of damage to a structure type as a percentage of market value and the Modified Mercalli Intensity in the region.

Damage algorithms were derived for two types of construction: (1) single family residential structures, and (2) industrial-commercial construction. These damage algorithms are given for four different relative strengths of construction as defined by quality factors (Q). Estimates developed by Whitman, et. al., [1973], permit establishment of basic structure quality factors. On this basis, structures in California built prior to 1933 were assigned Q=1 and structures built in California after 1933 were assigned Q=3.

For each type and strength level of building, estimates were developed showing the relationship between MMI and the percent damage sustained by structures. Earthquake intensity damage relationships were developed from the earthquake damage studies for industrial-commercial buildings presented by Barnes and Pinkham [1972]; Whitman, et. al., [1973]; Culver, et. al., [1975]; and Steinbrugge [1971]. For

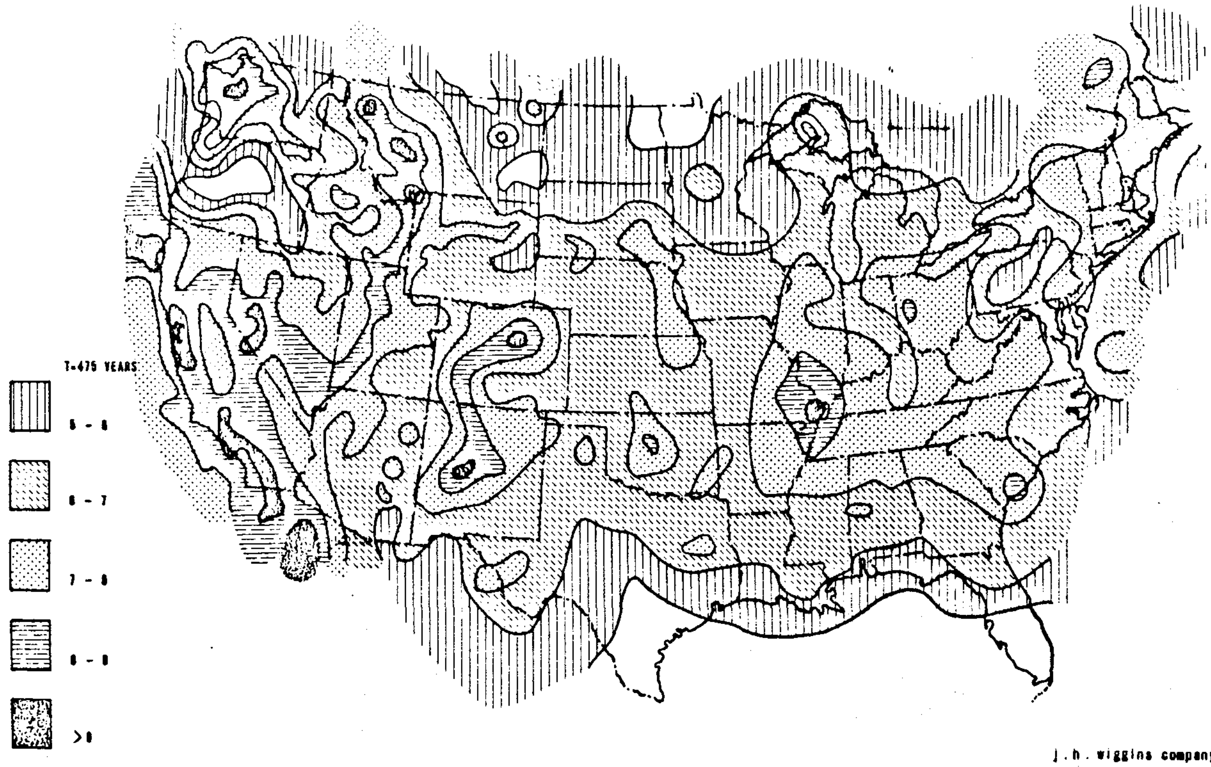


Figure 3-9. Modified Mercalli Intensity - Continental United States of America

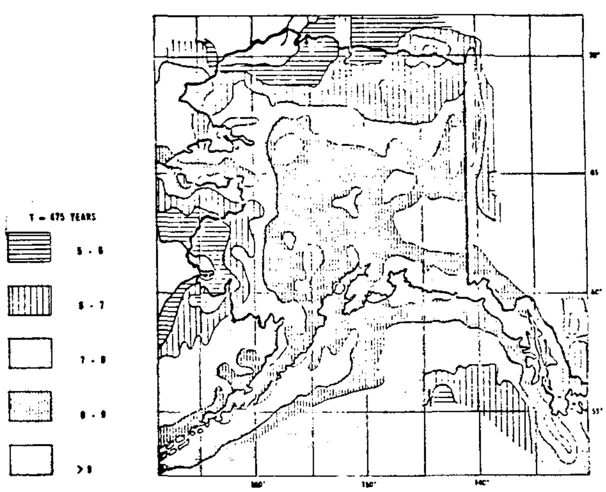


Figure 3-10. Modified Mercalli Intensity - Alaska

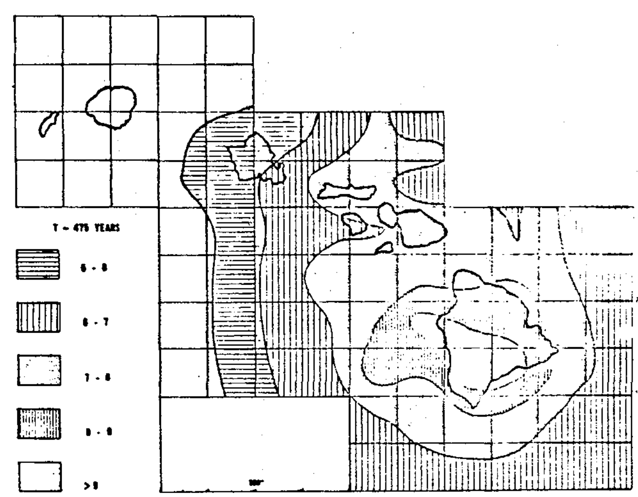


Figure 3-11. Modified Mercalli Intensity - Hawaii

residential buildings the data presented by Friedman [1970], Environmental Science Service Administration [1969], Steinbrugge [1971], and McClure [1973] were the basis for the damage relationships. The damage algorithms for the four qualities of structures are presented in Figures 3-12 and 3-13. These algorithms were used both to develop estimates of annual losses for earthquakes as well as estimates of the loss reductions achievable through application of building-strengthening mitigations to new structures.

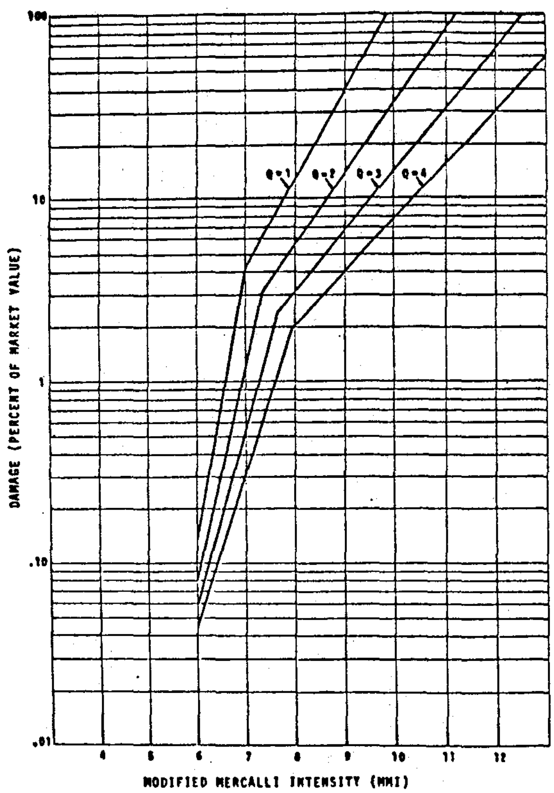


Figure 3-12. Damage Algorithm for Industrial-Commercial Structures

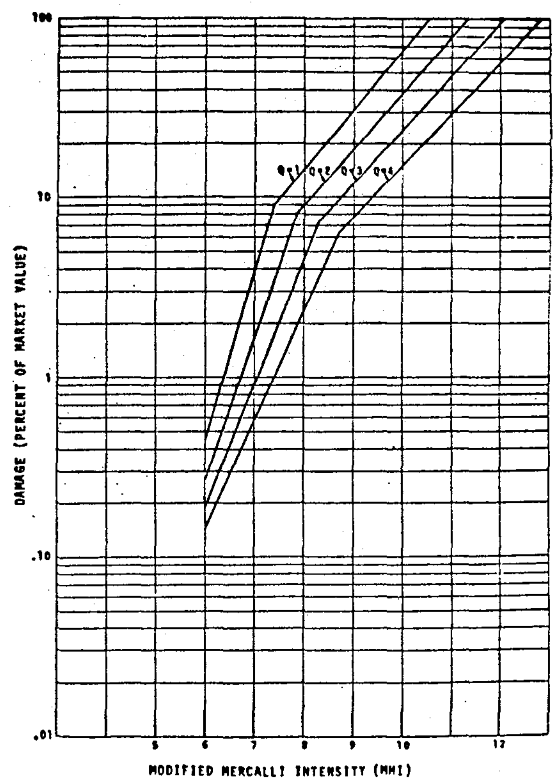


Figure 3-13. Damage Algorithm for Residential Structures

The time frame during which a building was constructed has a significant effect upon the relative strength of the structure. Thus, the age of the structure becomes important in the risk determination. A distribution of structure type by region throughout the United States was developed for two age categories and a separate distribution was developed for California [Wiggins, et. al., 1974; Hirschberg, et. al., 1977].

It has been noted by many that the natural force behind modification of the Uniform Building Code to include increased lateral force design parameters for engineered structures was the 1933 Long Beach earthquake. Due to adoption of these changes in building code specifications in California after 1933 the ability of new construction to withstand lateral forces was increased. Using the average relative strength change after 1933 developed by Whitman, et. al., [1973], descriptors of Q=1 and Q=3 for relative strengths of pre-1933 and post-1933 construction in California were developed. Using this relative strength, Q, and an age distribution of industrial-commercial structures and residential structures the following distribution by quality factor was estimated for California [Wiggins, et. al., 1974].

Type of Construction	Q=1	Q=3
Residential & Farm	18%	82%
Industrial & Commercial	20%	80%
Public & Institutional	19%	81%

Quality factors or relative strength of buildings throughout the other 49 United States were estimated on the assumption that when Federal Housing Authority (FHA) codes were put into effect after 1940, all post-1940 structures would have a relative strength twice that of pre-1940 structures. Figure 3-14 presents this generalized assumption. Utilizing the same basis as for California, the structure distribution, by relative strength factors, shown in Figure 3-15 was developed for the U.S. as a whole [Wiggins, et.al., 1974]

Having developed hazard intensities, as well as exposure and vulnerability of structures, as a function of geographic location, it is possible to estimate risk of loss for particular regions of the country. That is, by combining intensity expectancy with the damage algorithms for the exposed structures, a region's damage rate can be computed. The damage rate in this context is defined as the average annual percent loss expected to occur to exposed buildings.

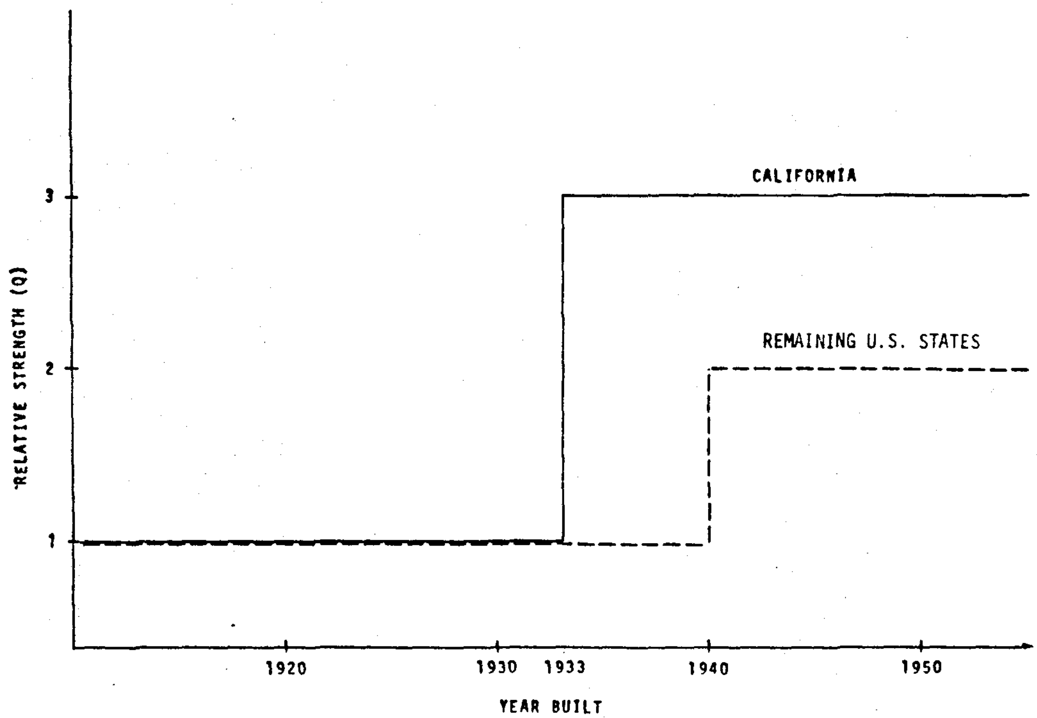


Figure 3-14. Relative Structural Strength by Year for California and the Remaining United States

Type of Construction	NORTHEAST Q=1 (%)	NORTHEAST Q=2 (%)	CENTRAL Q=1 (%)	CENTRAL Q=2 (%)	SOUTH Q=1 (%)	SOUTH Q=2 (%)	WEST (except CA) Q=1 (%)	WEST (except CA) Q=2 (%)
Residential & Farm	55.4	44.6	49.1	50.4	29.5	40.5	31.0	69.0
Industrial & Commercial	56.1	43.9	39.9	40.1	25.8	74.2	17.6	82.4
Public & Institutional	55.3	44.7	44.5	55.5	27.7	72.3	24.3	75.7

Figure 3-15. Post-1940 Structure Relative Strength Factors for Regions of the United States

Expansive Soils

Four major operations were required to develop estimates of expansive soils losses in the United States: (a) the mapping of U.S. expansive soils areas; (b) the assignment of whole counties or fractions of counties to the mapped areas; (c) determination of the size of the population at risk of exposure to expansive soils in each area, and (d) the development and use of a damage algorithm. [See Figure 3-16]

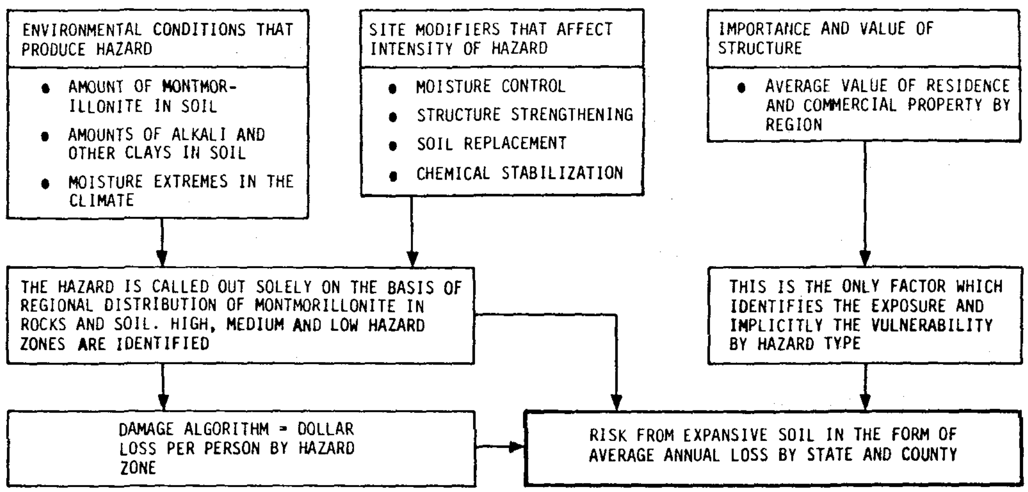


Figure 3-16. Expansive Soil Risk Determination Procedure

In the mapping phase of the project, all portions of the continental land area of the United States were assigned to one of three expansive soils zones. Criteria used to establish the low, moderate, and high zones depicted in the map correspond to shrink-swell guidelines set forth by the U.S. Soil Conservation Service. The quantitative method used by the Service [1971] for determining shrink-swell behavior of soil is referred to as COLE (coefficient of linear extensibility). COLE represents an estimate of the vertical component of swelling in a soil clod or ped. The following somewhat modified Soil Conservation Service definitions were used to establish the expansive soils zones depicted on the map:

<u>High</u>: Generally includes soils high in clay that are made up of a large percentage of montmorillonitic minerals. These soils have a COLE value usually greater than 6%.

Moderate: Generally includes soils containing moderate amounts of clay that also contain some montmorillonitic minerals. COLE values for these soils vary between 3% and 6%.

Low: Generally includes soil containing some clay; however, the clay consists mainly of kaolinite and/or other low shrink-swell clay minerals. These soils have COLE values generally lower than 3%.

Although the whole of any given local area may be assigned on the map to one of the three expansive soil zones, smaller portions of the included local area may have ratings both higher and/or lower than the rating shown for the whole of the zone to which the area is assigned. [See Figure 3-17].

In developing the map, all available state soils maps were utilized, but were extensively supplemented by comments secured from the various state soils scientists and the professional staff of the U.S. Soil Conservation Service. The mapped areas of moderate and high soil expansivity include essentially those areas which are chiefly underlain by montmorillonitic soils. There are over 12,000 soils series throughout the entire country, of which approximately 10% contain montmorillonite mineralogy. Of these, about 250 soils series are extensive enough to be shown as mappable units on intermediate scale generalized state soil maps. Therefore, for purposes of this study, only those large mappable units have been considered. On most state maps, soils are depicted as soil "associations." Generally, these associations consist of one to three soil "series." A hypothetical soil association may contain three soil series (A-B-C), with A always representing the dominant soil series followed by B, then C. Therefore, for purposes of this study, if soils in position A, A-B, A-C and B-C were montmorillonitic, then the entire soil association was given a moderate shrink-swell rating. In the case of the soil association consisting of one 1 (A) or 2(A-B) soil series, a high rating was assigned to the entire association providing the lone soil series (A) or one of the two soil series (A or B) contain montmorillonitic materials. For purposes of this study, the low expansive soil zone includes both low and non-expansive soil areas.

After the map was completed and examined, all states were assigned to one of three groups: (a) those containing no moderate or high expansive soils zones.

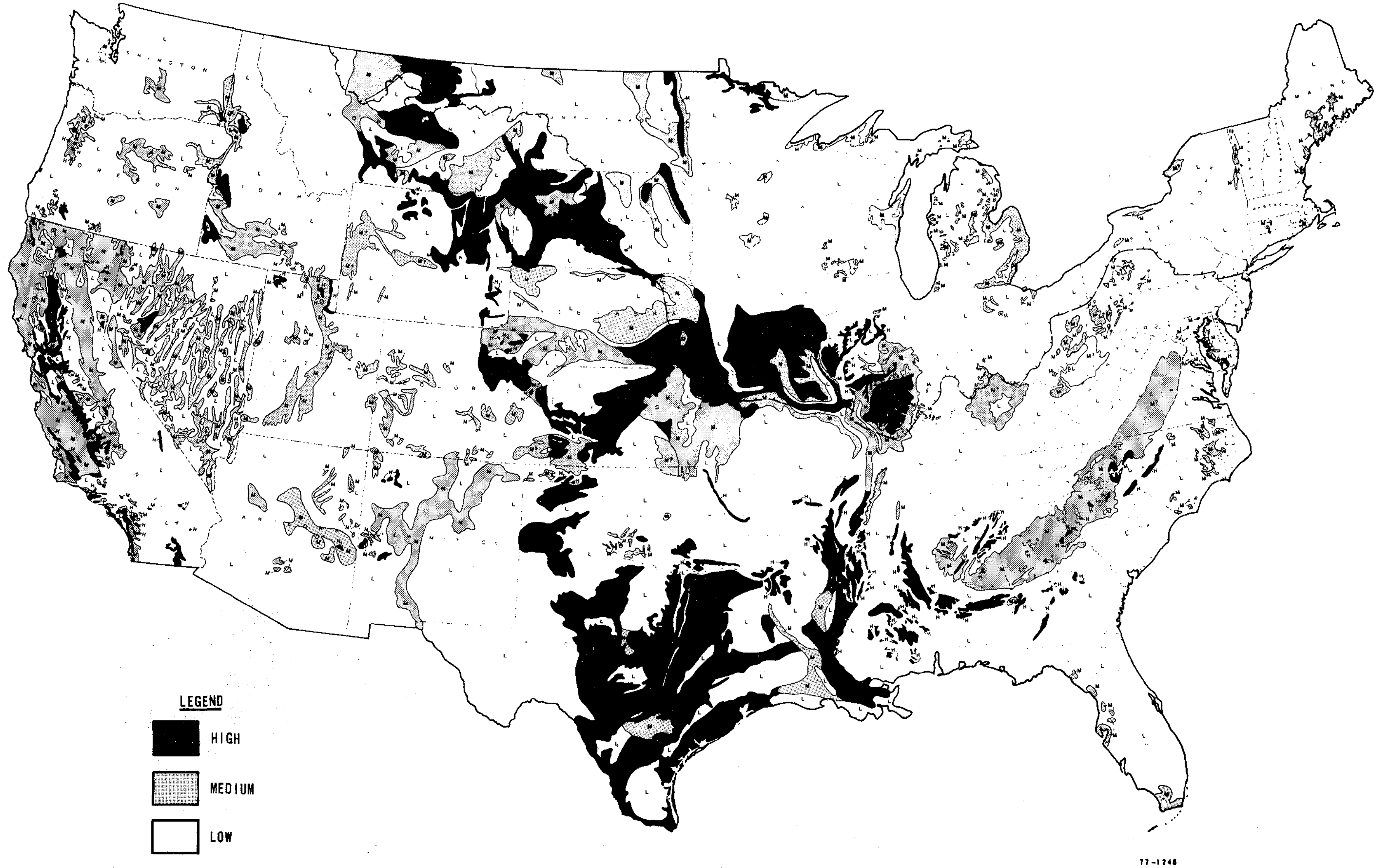


Figure 3-17. Expansive Soils Map prepared by James E. Slosson and Associates Engineering Geologists, February 1976

(b) those containing only moderate and low zones, and (c) those containing all three zones. For the purpose of developing a county-level data base necessary to the generation of loss estimates, whole counties in states having only moderate or low expansive soil zones were assigned to such zones based on the latitude-longitude location of each county seat. If that latitude-longitude location fell within a map zone, then the whole of the county was assigned to that zone. A somewhat different procedure was utilized to develop loss estimates for those states in which the map revealed all three soil expansivity zones. In those states, visual inspection of census maps was employed to assign appropriate fractions of counties to "high" and/or "moderate" zones. For the more populous counties, these estimates were based not on the proportion of the area of a county falling within the mapped zone, but on an estimate of the proportion of the county's total population residing within the mapped zone.

Since the damage algorithm utilized to estimate expansive soils losses was one derived from study of damage to single unit residential structures, the size of county populations exposed to expansive soils in an indicated category was reduced by the census-reported percentage of the county population residing in single family residential units.

The damage algorithm used to estimate expansive soils dollar losses was based entirely on two studies involving residential foundation data [Alfors, 1971; Allen, 1974; Smith and Allen, 1974]. Smith and Allen report that homeowners in Dallas County, Texas experience approximately 8470 residential foundation failures annually. The failures all involve expansive soil related problems (i.e., cracked walls, foundations, et cetera). It appears that approximately 84 percent of the foundation failures occur within high expansive soil areas, 14 percent relate to moderate expansive soil areas, and 2 percent occur in low expansive soil areas. In 1970, based on census data, there were approximately 312,100 residential foundations in Dallas County [Smith and Allen, 1974]. Of the total number of foundations, approximately 42 percent exist on high expansive soil, 27 percent occur on moderate expansive material and 31 percent were constructed on low expansive soil areas. Assuming that the average foundation repair cost is $1,650 [Smith and Allen, 1974],the following generalizations can be inferred:

Expansive Soil Rating	Total No. Foundation	Annual Foundation Failures		Cost per Foundation	Total Cost of Annual Foundation Failures
High	130,400	7115	X	$1,650.00 =	$11,739,750.00
Moderate	83,600	1186	X	$1,650.00 =	$ 1,956,900.00
Low	98,100	169	X	$1,650.00 =	$ 278,850.00
TOTAL	312,100	8470	X	$1,650.00 =	$13,975,500.00

$$\text{Damage Loss per Foundation per Year} = \frac{\text{Total Cost of Annual Foundation Failures}}{\text{Total Number of Foundations per Severity Rating}}$$

(1) The average annual damage cost for residential foundations in Dallas County, Texas for high expansive soil areas appears to be $90.00 per foundation per year. Foundation costs in moderate and low expansive soil regions are estimated to be $23.41 and $2.84 per foundation per year, respectively.

Expansive Soil Rating	Damage Loss per Foundation Per Year
High	$90.00
Moderate	$23.41
Low	$ 2.84

(2) The average population rate per dwelling in Dallas County is estimated, by 1970 census data, to be approximately 3 persons per housing unit. Therefore, residential foundation failure losses per capita are:

Expansive Soil Rating	Damage Loss per Capita per Year
High	$30.00
Moderate	$ 7.80
Low	$ 0.95

Expansive soil related losses have also been calculated for California and discussed in the California Division of Mines and Geology, Open File Report 72-2. The method used to establish the map severity code used in the California study is somewhat similar to the method incorporated in this report. Results of the California report [Alfors et al, 1971] are as follows:

Expansive Soil Rating	Damage Loss per Capita per Year
High	$22.30
Moderate	$ 6.92
Low	$ 1.14

Averaging the California statistics with those of Dallas County, the following figures result:

Expansive Soil Rating	Damage Loss per Capita per Year
High	$26.15
Moderate	$ 7.36
Low	$ 1.05

Accordingly, the damage algorithm used in this study assigned a loss of $26.00 per capita per year to single family residents in high zones; a damage loss of $8.00 per capita per year to single family residents in moderate zones; and a $1.50 damage loss per capita per year to single family residents in low zones. It should be noted that these approximate 1973 dollar loss rates.

Landslide

Landslides are comparatively uncommon, but naturally-occurring geologic events throughout much of the United States. Areas affected by landslides may range in size from several square feet up to several square miles.

Several factors influence the landsliding potential of an area. However, many of these factors do not have overall definite patterns to make them usable for a national or regional study. For purposes of this study, three general conditions have been considered in defining potential landslide areas. These factors are: topography, bedrock and precipitation.

Topography is a general term used to describe the actual physical shape and configuration of the earth's surface. Topographic relief refers to the vertical distance in elevation (relative to sea level) between hill tops or mountain summits and lowlands or valleys. Areas containing large elevation variations have high reliefs; likewise, minor elevation differences suggest areas of low relief [American Geologic Institute, 1972]. Topographic relief is important because it regulates erosion and other energy sources which, in turn, influence slope angle or gradient. Basically, the steeper a slope the more gravity can play a role in a landslide. The steeper, often cliff-like, slopes are susceptible to over-steeping and undercutting by stream erosion and therefore frequently are subject to landsliding.

Three topographic relief rates were developed and applied on a nationwide basis. Criteria used to establish the various relief categories are presented in the following table.

RELIEF RATINGS	CRITERIA
Steep	Moderately steep to steep hills and mountains (estimated relief greater than 2000' ± per 10 miles).
Moderate	Low to moderately steep hills (estimated relief 500± to 2000'± per 10 miles).
Low	Low hills and flat plains (estimated relief less than 500'± per 10 miles).

Table 3-4. Topographic Relief Rates

The nature of the bedrock material represents a primary factor controlling the distribution of landslides. Landslide susceptibility as it may relate to rock type is a function of: (1) inherent bedrock properties and (2) bedrock structure and geometry. It is the various inherent properties that dictate rock strength. As the rock strength decreases or is influenced by natural or man-made changes in energy conditions, landsliding becomes more prominent [Building Research Advisory Board, 1974]. As stated by Cleveland [1971], the strength of rocks, measured in terms of their resistance to weathering, is a basic geologic factor in the landslide process. Rock strength in this sense can be defined in a general way as the sum of the properties of a rock that governs its resistance to erosion by landsliding.

Precipitation largely controls the distribution and occurrence of landslide in that precipitation has a pronounced effect on the morphology of the landscape. Slope development is influenced by precipitation in two ways: (1) water which runs off the slope via established drainage courses, and (2) water that is absorbed by the slope soil and bedrock materials.

Runoff waters, if in sufficient volumne and velocity, may have the capacity to erode or undermine slope surfaces thereby removing slope support and causing landslide activity to occur.

Precipitation that infiltrates below the slope surface into the underlying materials may alter or change their strength by: (1) generating an increase in pore water pressure, (2) increasing the bulk density, (3) facilitating the partial removal of cementing agents and/or lubricating potential zones of inherent weaknesses within either the soil or rock material.

Rainfall is treated in terms of mean annual rainfall averages. Yearly rainfall rates have been divided into three basic categories: high, moderate, and low. An attempt was made to assign storm frequencies to each designated category. Table 3-5 presents estimated rainfall categories as well as storm frequencies which are interpretive values.

RAINFALL RATING (INCHES PER YEAR)	ESTIMATED NUMBER OF STORMS PER 10 YEARS
High (greater than 32")	10
Moderate (8" - 32")	1-4 (or 2.5)
Low (less than 8")	1

Table 3-5. Storm Frequency Estimates Related to Average Annual Rainfall

Generally, the regions with higher rainfall averages will also have a higher number of storms over a given interval of time. As previously mentioned, landslides are commonly associated with storm-years. Based upon this premise, those areas receiving more storms and consequently larger amounts of rain will generally have more landslides than those areas receiving less rainfall and storms, providing all other factors (bedrock and topography) remain constant.

Several assumptions were made during the development of the landslide intensity map. The following premises guided the map categorization.

(1) It has been assumed that adverse formations associated with landslide activity in times past will continue to have a high potential for landslide activity in the future, providing all factors (topographic relief and precipitation) remain constant.

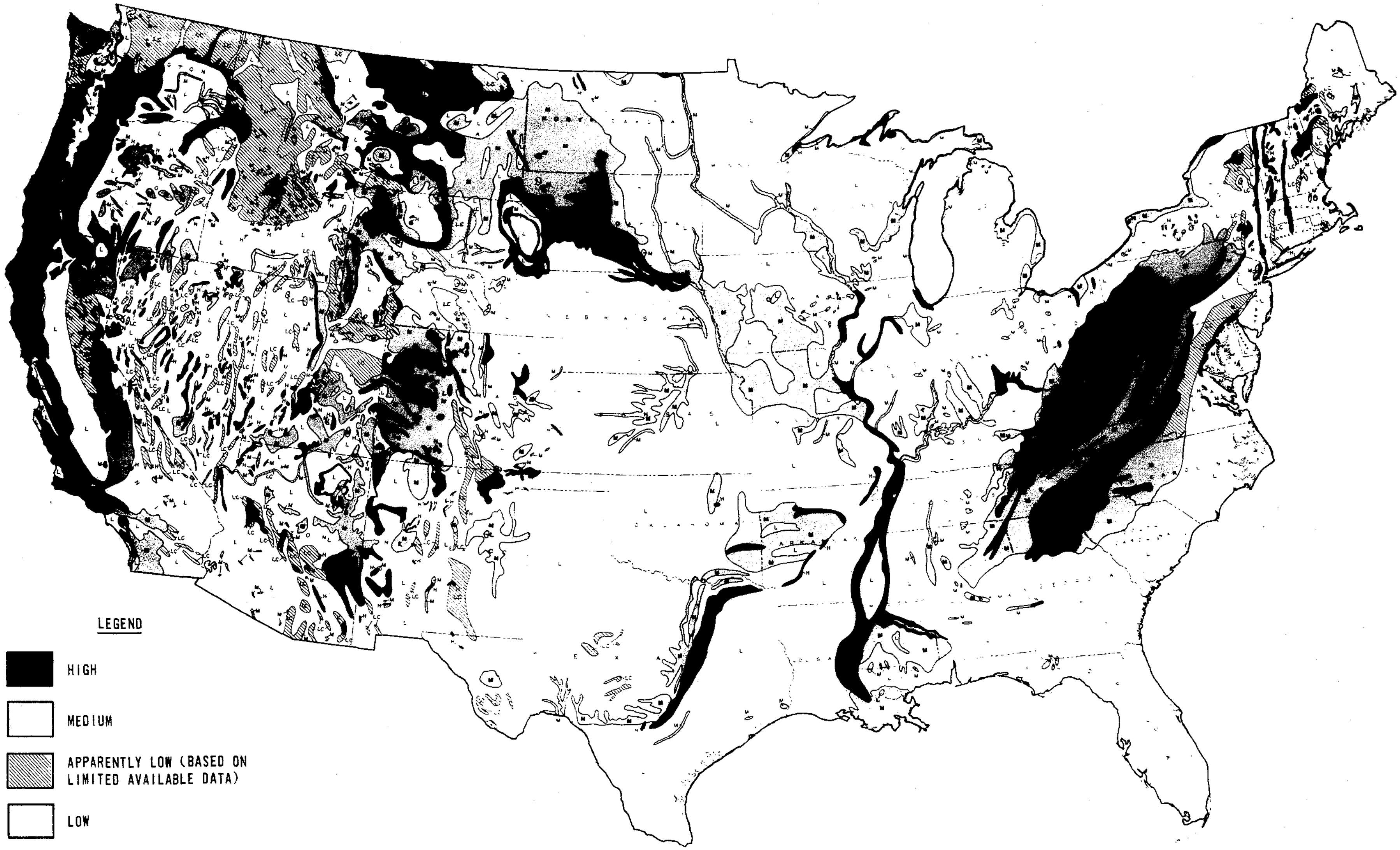
(2) Due to size and scale, it was not possible to differentiate vertical and lateral formation variations within a given adverse formation. Therefore, if a formation was considered to be adverse in one area, all other locations containing the same formation were also considered to be adverse.

(3) Although a given landslide potential rating was assigned to an area, local portions of that area may have ratings higher and/or lower than the ratings shown.

Recognizing the above limitations and constraints, a landslide intensity map was developed [Figure 3-18]. The landslide intensity map is an attempt to define landslide prone areas within the continental United States. This map incorporates the study results and data contained in the USGS "Preliminary Landslide Overview Map of the Coterminous United States", [Map MF-771], 1976. As mentioned before, this map is based on three principle factors: topography, bedrock, and precipitation. Topography and rock type were used to establish the high, moderate, and low landslide potential ratings defined on the landslide map, Figure 3-18. Mean annual rainfall data was also consulted in order to complete the map. Criteria used to establish the landslide potential rating are as summarized in Figure 3-19.

These criteria, when considered in conjunction with the rainfall for a given geographical area provide the basis for development of a landslide intensity scale. These relative intensities are presented in Figure 3-20.

The development of an exposure-vulnerability relationship for areas subjected to varying landslide intensities proves to be a very difficult assignment. Due to the limited data in this area, it was necessary to develop building loss estimates from landslides using estimates of damage on a per person basis as presented in the existing literature.



Note: Landslide potential based upon study results and USGS "Preliminary Landslide Overview Map of the Coterminous United States" [MF-771] printed in 1976

Figure 3-18. Areas of Adverse Formations and Varying Topographic Relief Which Identify Categories for Landslide Potential

High (H): An area of steep topographic relief with a known landslide-prone bedrock formation (rock type).

High = Adverse Formation + Steep relief

Moderate (M): An area of moderate topographic relief with a known landslide-prone bedrock formation (rock type).

Moderate = Adverse Formation + Moderate relief

Low (Ls): An area of steep topographic relief without a known landslide-prone bedrock formation (rock type). Of the two low designations, (Ls) has a higher landslide potential.

Low (steep) = No Adverse Formation + Steep relief

Low (L): An area of low topographic relief and may or may not contain a known landslide-prone bedrock formation (rock type); or moderate relief with no known landslide-prone bedrock formation.

Low = No Adverse Formation + Moderate relief
= No Adverse Formation + Low relief
= Adverse Formation + Low relief

Figure 3-19. Landslide Potential Rating Criteria

Landslide Potential Map Rating	Rainfall in inches	Relative Intensity (Highest ranking is the most severe)
High	32"	XII
	8-32"	X
	8"	IV
Moderate	32"	XI
	8-32"	IX
	8"	III
Low (Steep)	32"	VIII
	8-32"	VI
	8"	II
Low	32"	VII
	8-32"	V
	8"	I

Figure 3-20. Landslide Intensity Ranking Based on Rock Type, Topography and Precipitation

Exposure to landslide was determined from structure values by county, the population of the county, and a computation of average structure value per person in the county. No attempt was made to distinguish between various types of buildings such as residential, industrial, or commercial. It was assumed that dwellings usually suffer from landslides more frequently than do industrial-commercial properties, thus loss estimates may trend toward the high side.

Utilizing estimated costs of damages from landsliding in Allegheny County, Pennsylvania [Briggs, et al, 1975] and estimated losses from landslides occurring in California [Brabb and Taylor, 1972 and Slosson, 1969], a table of landslide loss per capita as a function of intensity was developed.

Reference	Region	Intensity	Loss Per Person (1970 $)
1.	California	XII	$140.00
		IX	23.00
		V	1.10
2.	California	XII	53.00
		IX	35.00
		V	1.00
3.	Allegheny Co.	XII	1.20
4.	Marin Co.	X 1/2	14.00
	San Mateo Co.	X 1/2	6.10
	Contra Costa Co.	IX	2.60
	Napa Co.	IX	1.80
	Sonoma Co.	XII	.88
	Alameda Co.	XII	.35
	Santa Clara Co.	V	.18
5.	Marin Co.	X 1/2	5.30
	San Mateo Co.	X 1/2	7.40
	Contra Costa Co.	IX	11.00
	Napa Co.	IX	21.00
	Sonoma Co.	XII	39.00
	Alameda Co.	XII	5.30
	Santa Clara Co.	V	2.10
6.	Los Angeles Co.	V	2.10

Table 3-6. Landslide Damage per Person Normalized to 1970 Dollars

Utilizing the data contained in the landslide damage per person table, an average loss per person per year was established for the following intensity zones.

ZONE	INTENSITY RANGE	DOLLAR LOSS PER PERSON PER YEAR (1970$)
3	IX - XII	$ 4.25
2	V - VIII	.80
1	I - IV	.05

The landslide potential map and estimate of the precipitation made it possible to establish an intensity range for each U.S. county, and thus define a county risk zone. By knowing the population and structure value in a specific county and the risk zone for that county, it is possible to estimate the dollar loss resulting from landslides on an annual average basis. The risk determination procedure discussed above is summarized in Figure 3-21.

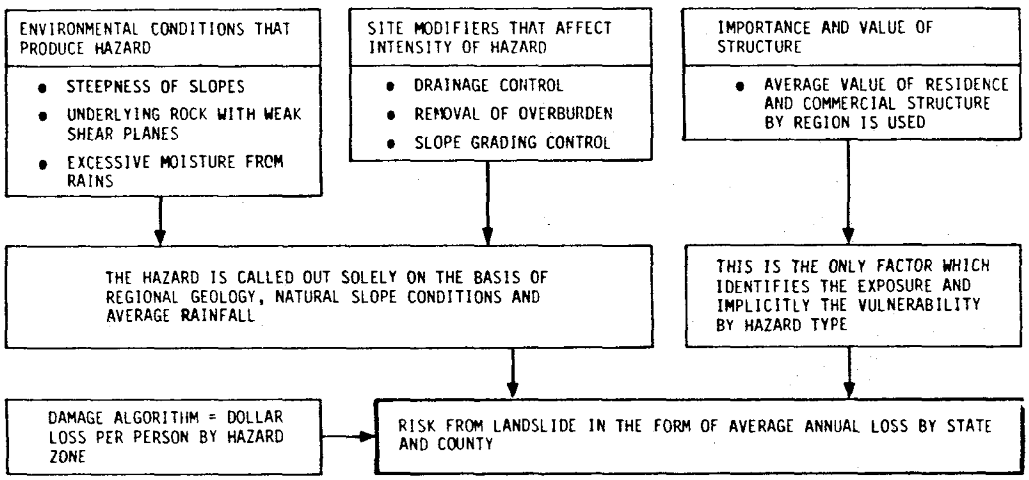


Figure 3-21. Landslide Risk Determination Procedure

Water Hazards

The water hazards considered in this study are riverine flooding, storm surge, and tsunami. Riverine flooding is common to every state while storm surge is predominantly of concern to states on the Gulf and Atlantic coastlines. The risk of tsunami is limited to states contiguous to the Pacific Ocean. The following sections describe briefly the hazard, exposure, and vulnerability models, the damage algorithms, and the risk determination procedures utilized for each water hazard. Discussion of the models and the study methods is contained in "Natural Hazards" Storm Surge, Riverine Flooding, Tsunami Loss Models", by Lee, Chrostowski and Eguchi, J.H. Wiggins Company, [1976].

Riverine Flooding

Although the riverine flooding hazard is ubiquitous throughout the United States, local variables are of such importance and vary so substantially from one riverine flood plain to another, that it is not yet possible to present the national hazard model for riverine flooding which specifically addresses each individual flood plain in the United States. Accordingly, a "regional" flood damage model was developed for the United States as part of this project. After an extensive literature review, the project staff determined that the simulation model previously developed by Friedman [1966, 1972] and reported by White [1975] was adaptable to this study. In the Friedman model, a Monte Carlo approach was utilized to determine which, among a large number of modeled cities, would be affected by a flood in any given year, to identify the magnitude of the flood which would be experienced, and to determine the damage that would be experienced by the flood-affected cities. This same approach was utilized in the regional flood models developed for this study. Although the general approach taken in the development of these models was that suggested by Friedman, the specific parameters of the new models are significantly different from those utilized by Friedman. For purposes of the model and the resulting analysis of riverine flood losses, the nation was divided into ten regions [Figure 3-22] using physiographic, climatologic, and demographic factors as the distinguishing parameters. Separate hazard and exposure models were developed for each region. The hazard model is based on six flood types depending on their annual probability of occurrence [See Figure 3-23].

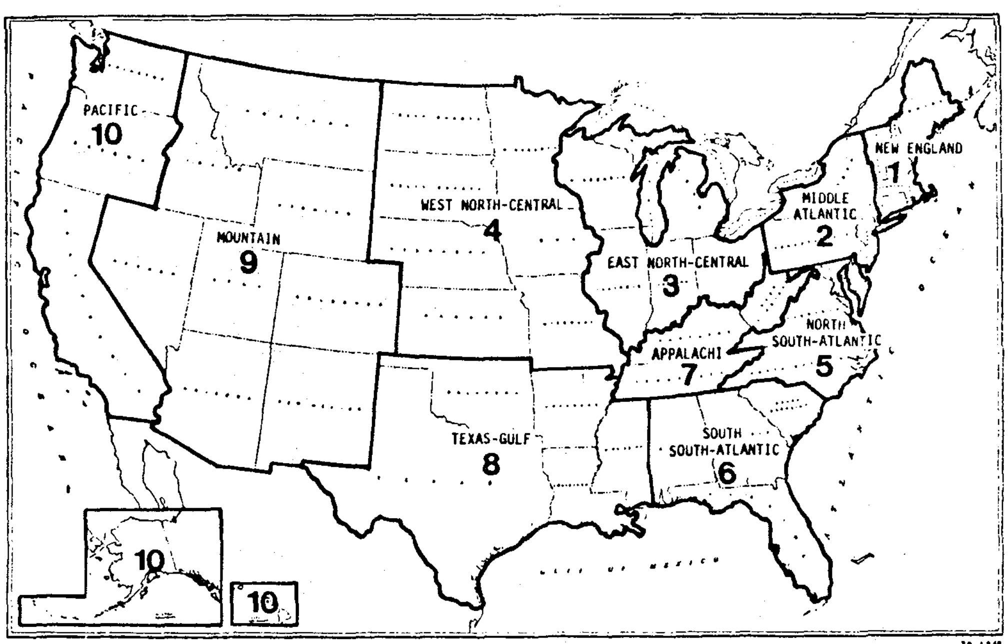


Figure 3-22. Regionalized Model for Riverine Flooding

FLOOD TYPE	RETURN PERIOD	PROBABILITY OF EQUALLING OR EXCEEDING	PROBABILITY OF OCCURRENCE	CUMMULATIVE PROBABILITY OF OCCURRENCE
No flood			.50	.50
	2 years	.50		
A			.30	.80
	5 years	.20		
B			.10	.90
	10 years	.10		
C			.06	.96
	25 years	.04		
D			.02	.98
	50 years	.02		
E			.01	.99
	100 years	.01		
F			.01	1.00

Figure 3-23. Probability of Occurrence

The depth associated with each flood type was regionalized on the basis of physiography and mean annual rainfall. Only four relationships were needed. A typical one is shown below [See Figure 3-24].

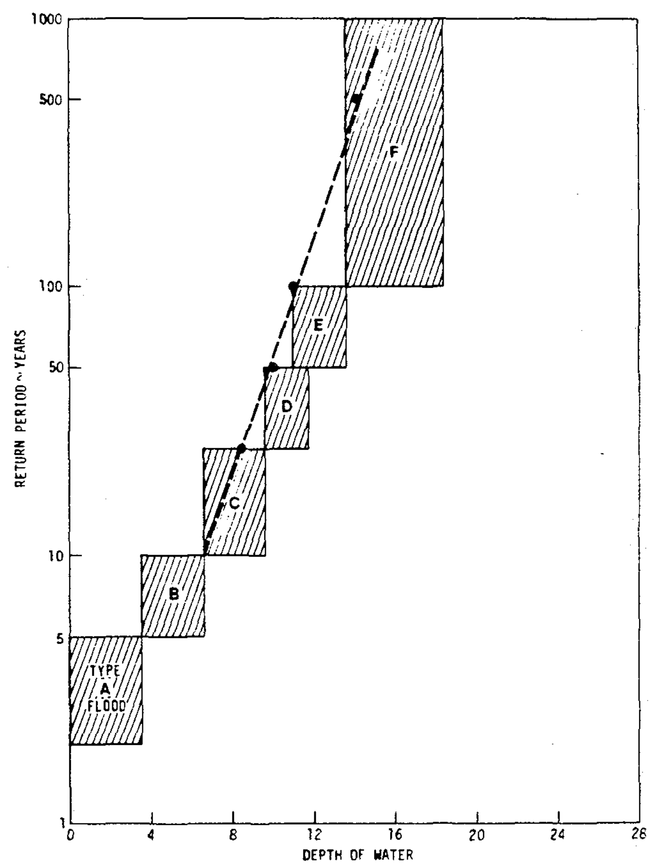


Figure 3-24. Hazard Model - Plains - High Rainfall

The exposure model also was regionalized.

First the number of places (cities and towns with more than 1,000 people) with a flood problem was defined. The following breakdown by city provided by Friedman [1972] was used.

City Size	Number of Places with Flood Problems (Incorporated Municipalities)
Greater than 100,000	140
50,000 - 100,000	204
25,000 - 50,000	390
10,000 - 25,000	903
5,000 - 10,000	992
2,500 - 5,000	1,098
1,000 - 2,500	1,812

These data were apportioned into the ten regions in proportion to the total number of cities of each size category in the region. Then the number of structures on the flood plain and their distribution across the flood plain was estimated.

Only two sources are immediately available for determining the number of residential structures on flood plains: a 1966 study performed for HUD and a 1974 study by Schneider and Goddard. Using these two sources, two relationships of the percent of dwellings on the 100-year flood plain as a function of city-size were developed: one for the central and coastal plains and one for the western and eastern highlands. A further breakdown into the six specific flood zones was performed using only the 1966 HUD data. The value of each residential unit was estimated and different values were obtained for different regions and city sizes.

An estimate of the total number of commerical-industrial-governmental properties in the United States was made in a somewhat coarser fashion. This national total was then apportioned to the ten regions and within each region further apportioned to the cities using a derived relationship for the number of employees per property as a function of city size. These properties were distributed to the six flood zones using the same relationship developed for residential structures.

The damage algorithms are based on empirical depth-damage curves. The current depth-damage curves reported by Grigg and Helweg [1975] were used with slight modification.

The five structure types considered are:

- One story, without basement
- Two or more stories, without basement
- One story, with basement
- Two or more stories, with basement
- Mobile home

The approach taken for commercial structures was to use the residential damage curves weighted by a constant factor of 0.3. The rationale for using this particular weighting factor was that it was the value chosen by Friedman after a review of National Weather Service annual estimates of flood damages. The vulnerability model, or the breakdown of the number of structures of each type, was developed from 1970 census data and a 1967 sonic boom study.

The technique used here to estimate average annual damage is as follows:

A trial is run in which each city in the model is tested. A random number generator, operating according to the rules of the probability-of-occurrence model, denotes the occurrence or non-occurrence of a flood at each city. If a flood occurs for a given community, the probability-of-occurrence model specifies the flood type (i.e., flood magnitude). Fifty percent of the time there is no flood, thirty percent of the time there is a 2 - 5 year flood, ten percent a 5 - 10 year flood, etc. When a flood of a particular type occurs, the damage is determined by summing over all of the affected zones. Within each zone the exact water depth above the first floor is again denoted using the random number generator operating within the depth ranges defined by the hazard model.

Each trial produces a set of regional damages which might occur. In other words, it is just one set out of all of the millions of possible damage states. To obtain an estimate of the average annual damage, therefore, a number of trials are run for the subject year. The average of these trials provides an estimate of the average annual damage.

The use of the model described above prevents us from providing county-level estimates of riverine flood losses. Thus, the approach to the riverine flood analysis was fundamentally different from that used for all of the other natural hazards examined in this study. Nonetheless, the basic scheme used in the riverine flood analysis [See Figure 3-25] is generally similar to that applied to other hazards. Only the details of its application and the level of detail generated by the model differ from the approach characteristic of the analysis of other study hazards. Also to be noted is the fact that selected data outputs from the riverine flood model then were subjected to manual calculations for purposes specific to the loss and loss reduction analyses reported in Chapters IV and V.

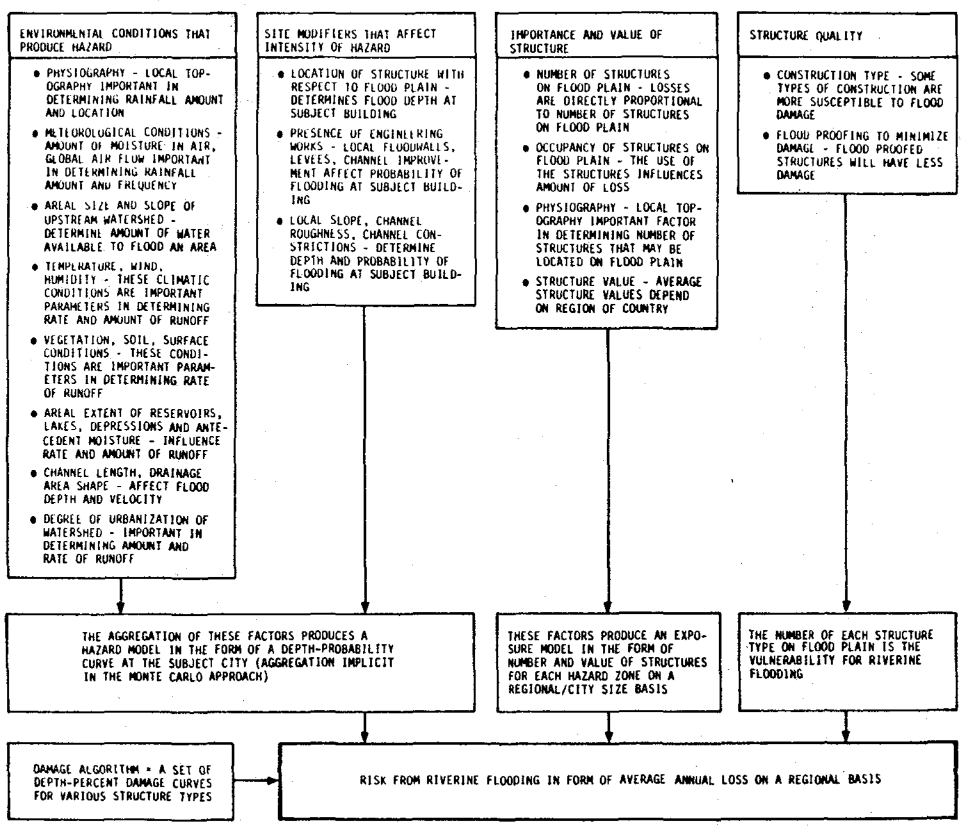


Figure 3-25. Riverine Flooding Risk Determination Process

Storm Surge

Storm surge is the increase in water level above normal tidal action caused by storm conditions. In the United States a surge-producing storm is usually either a hurricane, which develops from a tropical weather disturbance, or a "Northeaster" which develops in the North Atlantic. Thus, the storm surge hazard is primarily of concern on the Atlantic and Gulf Coasts of the United States. The risk determination procedure for storm surge is summarized in Figure 3-26.

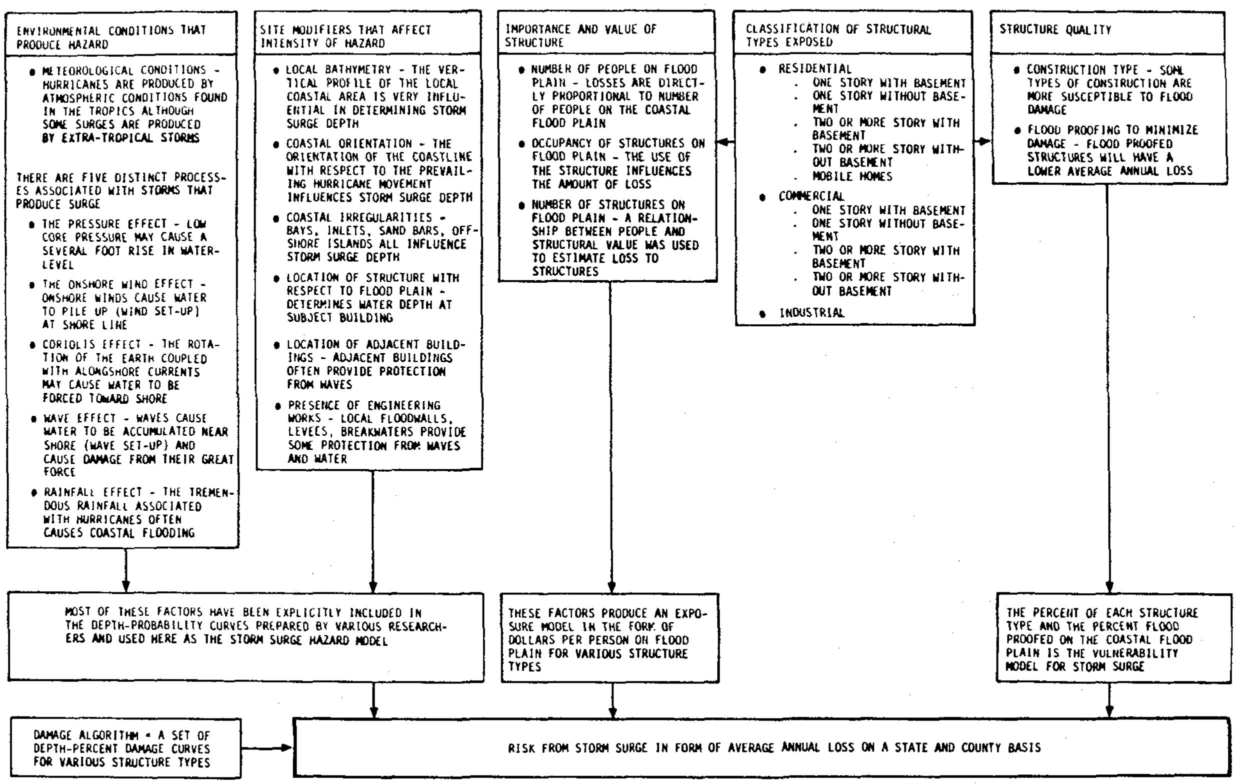


Figure 3-26. Storm Surge Risk Determination Procedure

The purpose of the hazard intensity model is to associate probabilities of annual occurrence with given tide heights. This is accomplished by developing plots of tide height versus frequency of occurrence for specific locations. Figure 3-27 shows a typical tide/frequency plot. This approach gives either the return period for exceeding a certain tide height, or the annual probability of exceeding that height.

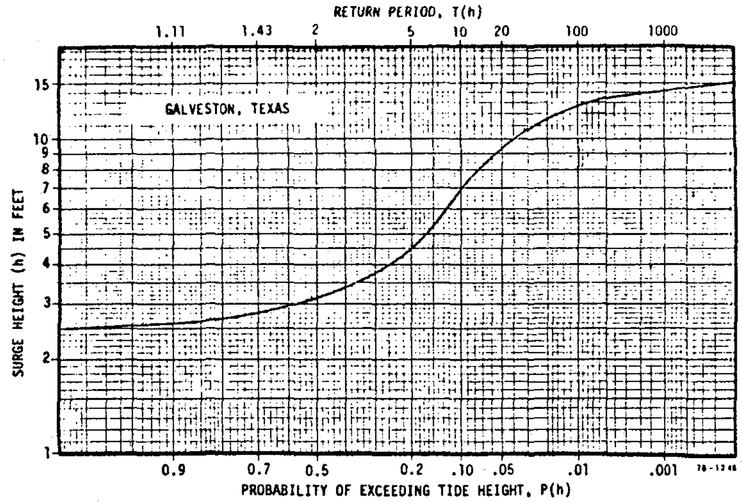


Figure 3-27. Typical Tide/Frequency Curve

At the present time, two methods are used by ecologists for generating tide/frequency plots at specific locations: statistical analysis of historical data or synthetically generated tide data based upon generalized statistical hurricane data and hydrodynamic surge model.

For this study, the historical method was used wherever possible. This method assumes that the tides of present and future storms can be related to past history. Therefore, actual storm tide data that has been compiled at a location for a limited number of years is used to calculate a tide/frequency curve. For purposes of predicting storm tides of events with long return periods, the curve must be cautiously extrapolated. This method has the advantage of utilizing real storm data which inherently account for the random occurrence of the storm tide with the astronomical tide. The disadvantage of this method lies in the limited time span of most recorded historical data and the need to extrapolate when considering events with small probabilities of occurrence.

Storm surge hazard intensities, in the form of tide/frequency curves, were developed on a county basis for states along the Gulf and Atlantic Coasts. In general, only coastal counties are involved; however, in several states inland counties are included because of their low elevation relative to mean sea level. The delineation of the hazard intensities on a county basis enables damage estimations to be produced which can be used to assess problem areas.

Whether or not people are exposed to the storm surge hazard depends on their location relative to mean sea level. The largest surge height used in this study is 23 feet above mean sea level (msl). For this study, therefore, people living in coastal areas below 23 feet msl may be exposed to some degree of storm surge risk.

An estimate of the distribution of people and buildings by elevation intervals (i.e., one-foot increments) was developed for each county along the Atlantic and Gulf Coast. Only one other study to date [Friedman and Roy, 1966] has attempted to define such an extensive exposure breakdown. Data from that study was incorporated into this one, particularly in those regions where more current or more accurate information was not available.

The exposure model is only roughly defined because of the following:

- Distribution Increments - damage varies with water height, thus, the population exposed must be distributed to relatively small elevation increments (one-foot increment). This is a much finer increment than that for which population information is available.

- Type of Data Available - topographic and storm-evacuation maps at best only resolve elevation contours down to five-foot elevations. Thus, approximate relationships had to be developed to distribute the populace into one-foot elevation increments.

- Quantity of Data - analysis of all available topographic and storm-evacuation maps to estimate exposed population was not feasible within the constraints of this project.

The exposed population and their distribution must be considered in relation to manmade or natural barriers that might protect all or part of the county. Where large seawalls exist and protect all or nearly all of the county population to a specified height, the natural hazard model was modified by setting the surge probability for depths below the height to zero. In those cases where seawalls or levees protect only a limited area of a county, the exposure model for that county was reduced based by the percentage of the population estimated to be protected.

Table 3-7 summarizes the 1970 county exposure together with known information on the protective measures. It was assumed that the first floor of all structures would be 2 feet above the grade due to the prevalence of foundations and basements.

The damage relations used for storm surge consist of a set of depth-damage curves. These damage curves provide an estimate of the percent of damage as a function of water height above the structure's first floor. There are two types of damage associated with storm surge. The first type is due to "stillwater" effects and is similar to that caused by riverine flooding except slightly more severe because of the corrosiveness of seawater. The second type of damage is caused by wave action which imposes large forces on the structure.

Because the degree of damage is also a function of structure type, ten separate structural categories were considered:

- One-story residential without basement
- One-story residential with basement
- Two-story residential without basement
- Two-story residential with basement
- One-story commercial without basement
- One-story commercial with basement
- Two-story commercial without basement
- Two-story commercial with basement
- Industrial buildings
- Mobile homes

These damage curves were prepared for each structure type to reflect different levels of wave action: 1. stillwater; 2. light to moderate wave action; and 3. moderate-to-heavy wave action. A typical damage-depth curve is presented in Figure 3-28. These curves represent average damage and are only indicative of how a large sample of structures would be damaged.

STATE	COUNTY	EXPOSED POPULATION (MSL - 20)	POP. DIST. CURVE	DAMAGE CURVE	HAZARD (H) OR EXPOSURE (E) REDUCTION
TX	CAMERON	4,962	1	2	
	WILLACY	99	2	2	
	KENEDY	0	2	2	
	KLEBERG	15	3	2	
	NUECES	26,262	1	2	(E) 50% reduc. due to 13' seawall at Corpus Christi
	SAN PATRICIO	11,550	3	2	(H) 16' cutoff--100-yr wall at Freeport
	ARANSAS	5,379	2	2	
	REFUGIO	645	1	2	
	CALHOUN	14,478	3	2	
	JACKSON	813	3	2	
	VICTORIA	0	3	1	
	MATAGORDA	4,881	1	2	
	BRAZORIA	35,226	3	2	
	GALVESTON	140,319	2	2	(E) 95% reduc--15' seawall at Galveston, levee at Tex. City
	HARRIS	29,451	1	2	
	CHAMBERS	1,365	2	2	
	JEFFERSON	94,329	3	2	(E) 40% reduc--100-yr seawall at Pt. Arthur
	ORANGE	39,183	1	1	
LA	CAMERON	8,193	2	3	
	CALCASIEU	143,520	3	2	
	JEFFERSON DAVIS	15,594	3	2	
	ACADIA	13,275	1	2	
	VERMILION	42,999	2	3	
	LAFAYETTE	0	1	2	
	ST. LANDRY	2,184	1	1	
	ST. MARTIN	24,300	2	1	
	IBERIA	57,399	2	3	
	PT. COUPEE	0	3	1	
	ST. MARY	46,740	2	3	(E) 30% reduc.--13'-14' levee at Pt. Arthur
	IBERVILLE	30,000	3	1	
	W. BATON ROUGE	0	1	1	
	E. BATON ROUGE	0	1	1	
	TERREBONNE	46,899	2	3	
	ASSUMPTION	19,599	2	2	
	ASCENSION	36,999	3	1	
	LAFOURCHE	32,199	2	3	
	ST. CHARLES	21,840	2	2	(H) 9' cutoff--storm evac. maps show levees
	ST. JOHN THE BA.	23,001	2	2	
	LIVINGSTON	1,734	2	2	
	TANGIPAHORA	2,325	2	2	
	ST. TAMMANY	57,999	3	2	storm evac. maps and conversation show approx. (H) 9'--10' wall or levee protection use 9' cutoff
	JEFFERSON	362,760	2	2	
	ORLEANS	574,001	2	2	
	PLAQUEMINES	25,224	2	3	
	ST. BERNARD	51,186	2	3	
	ST. JAMES	19,731	2	1	
MS	HANCOCK	6,843	3	3	(H) 6' cutoff--levee from Waveland to Bay St. Louis
	HARRISON	56,112	2	3	(H) 9' cutoff--levee approx. 8' 12'
	JACKSON	54,969	2	3	(H) 5' cutoff--5' beach erosion project
AL	MOBILE	6,3348	2	3	
	BALDWIN	15,426	2	3	
FL	ESCAMBIA	39,240	2	2	
	SANTA ROSA	41,370	2	2	
	OKALOOSA	38,046	2	2	
	WALTON	591	3	2	
	BAY	16,338	2	3	
	GULF	6,939	2	2	
	FRANKLIN	5,934	2	2	
	WAKULLA	1,455	2	3	
	JEFFERSON	24	2	3	
	TAYLOR	504	2	3	
	DIXIE	522	2	3	
	LEVY	7,752	2	3	
	CITRUS	2,721	2	3	
	HERNANDO	285	2	3	
	PASCO	5,739	3	3	
	PINELLAS	163,200	2	2	
	HILLSBOROUGH	98,700	2	2	
	MANATEE	28,035	2	2	
	SARASOTA	64,587	3	3	
	CHARLOTTE	20,598	3	2	
	LEE	43,311	1	2	
	COLLIER	26,307	2	3	
	MONROE	43,443	2	3	

STATE	COUNTY	EXPOSED POPULATION (MSL - 20)	POP. DIST. CURVE	DAMAGE CURVE	HAZARD (H) OR EXPOSURE (E) REDUCTION
FL	DADE	750,000	2	2	(E) 30% reduc.--partial wall/local protection
	BROWARD	453,200	2	2	
	PALM BEACH	226,641	2	2	
	MARTIN	13,155	2	2	
	ST. LUCIE	34,278	2	2	
	INDIAN RIVER	27,255	2	2	
	BREVARD	137,064	3	2	
	VOLUSIA	112,770	2	2	
	FLAGLER	2,052	2	3	
	ST. JOHNS	14,325	2	2	
	DUVAL	23,487	2	3	
	NASSAU	7,638	2	3	
GA	CAMDEN	4,725	2	3	
	GLYNN	26,739	2	3	
	MC INTOSH	3,075	1	3	
	LIBERTY	444	3	3	
	BRYAN	900	1	3	
SC	CHATHAM	64,716	1	3	(E) 20% reduc.--7'-9' seawall at Savannah Beach
	JASPER	900	1	3	
	BEAUFORT	48,744	2	3	
	COLLETON	900	1	3	
	DORCHESTER	0	2	2	
	CHARLESTON	194,715	2	3	(E) 20% reduc.--7' seawall fronting Charleston
	BERKELEY	900	2	2	
	GEORGETOWN	12,537	2	3	
	HORRY	13,176	2	3	
NC	BRUNSWICK	3,261	2	3	
	NEW HANOVER	28,809	1	2	
	PENDER	681	1	2	
	ONSLOW	61,653	2	2	
	JONES	0	2	2	
	CARTERET	31,602	2	2	
	CRAVEN	17,646	2	2	
	PAMLICO	9,468	2	2	
	BEAUFORT	35,649	2	2	
	HYDE	5,571	2	2	
	DARE	6,993	2	2	
	TYRELL	3,804	2	2	
	WASHINGTON	14,037	2	2	
	MARTIN	582	3	2	
	BERTIE	2,613	2	2	
	HERTFORD	0	2	2	
	GATES	0	2	2	
	CHOWAN	9,174	2	2	
	PERQUIMANS	6,174	2	2	
	PASQUOTANK	26,823	3	2	
	CAMDEN	5,451	2	2	
	CURRITUCK	6,975	2	2	
VA	VIRGINIA BEACH	185,493	2	3	(E) 20% reduc.--seawall on Atlantic side
	CHEASAPEAKE	17,250	1	2	
	PORTSMOUTH	110,001	1	2	
	NORFOLK	304,800	1	2	
	NANSEMOND	1,107	1	2	
	ISLE OF WIGHT	3,483	1	2	
	NEWPORT NEWS	102,240	1	2	(E) 10% reduc.--7' seawall on Bay side
	HAMPTON	126,000	1	3	(E) 40% reduc.--3 seawalls along Chesapeake Bay
	YORK	7,770	1	2	
	GLOUCESTER	2,526	1	3	
	MATHEWS	2,841	3	3	
	MIDDLESEX	1,119	2	2	
	LANCASTER	2,391	2	2	
	NORTH UMBERLAND	1,269	1	2	
	WESTMORELAND	2,757	1	2	
	NORTHAMPTON	2,130	3	3	
	ACCOMACK	3,933	2	3	

STATE	COUNTY	POPULATION (MSL - 20)	POP. DIST. CURVE	DAMAGE CURVE	HAZARD (H) OR EXPOSURE (E) REDUCTION
MD	ST. MARYS	2,400	2	2	
	CALVERT	2,568	3	2	
	ANNE ARUNDEL	22,701	3	2	
	BALTIMORE CITY	135,000	1	2	
	BALTIMORE	71,751	1	2	
	HARFORD	4,731	1	2	
	CECIL	3,669	1	2	
	KENT	3,933	2	2	
	QUEEN ANNES	3,000	2	2	
	TALBOT	5,982	1	2	
	DORCHESTER	29,400	2	2	
	WICOMICO	9,264	2	2	
	SOMERSET	17,775	2	2	
	WORCESTER	2,541	2	2	
DE	SUSSEX	6,438	2	3	
	KENT	708	2	2	
	NEW CASTLE	18,624	3	2	
NJ	SALEM	26,577	2	2	
	CUMBERLAND	6,624	2	2	
	CAPE MAY	47,310	2	3	
	ATLANTIC	100,485	2	2	(H) 8' cutoff--bulkheads at Atl. City & Ocean City
	BURLINGTON	501	3	2	
	OCEAN	72,918	2	2	
	MONMOUTH	100,800	3	2	(E) 20% reduc.--seawalls at Keansburg & Monmouth Beach
	MIDDLESEX	66,000	2	2	
	UNION	50,700	3	1	
	ESSEX	102,999	3	1	
	HUDSON	114,600	3	1	
NY	RICHMOND	25,380	3	2	
	NEW YORK	166,500	3	2	
	KINGS	896,766	3	2	(H) 7' cutoff--due to primary & secondary beach dunes on Atl. side
	QUEENS	297,750	3	2	
	NASSAU	209,520	3	2	
	SUFFOLK	150,330	3	2	
	BRONX	170,895	3	2	
	WESTCHESTER	9,732	3	2	
CT	FAIRFIELD	111,000	3	2	(E) 30% reduc.--100-yr wall at Stamford
	NEW HAVEN	72,498	3	2	
	MIDDLESEX	10,320	3	2	
	NEW LONDON	63,546	3	2	(E) 10% reduc.--100-yr wall at Powcatuck
RI	WASHINGTON	15,060	2	2	
	KENT	12,999	2	2	
	PROVIDENCE	39,600	2	2	(H) 15' cutoff--100-yr wall fronting Providence
	BRISTOL	13,998	2	2	
	NEWPORT	53,631	2	2	
MA	BRISTOL	60,000	3	2	(H) 14' cutoff--100-yr wall protecting New Bedford
	PLYMOUTH	44,325	3	3	
	BARNSTABLE	22,830	3	3	
	DUKES	2,943	3	3	
	NANTUCKET	10,920	3	3	
	NORFOLK	17,499	1	2	
	SUFFOLK	50,001	1	3	
	ESSEX	88,182	1	3	
NH	ROCKINGHAM	10,743	1	3	
ME	YORK	4,386	1	3	
	CUMBERLAND	14,886	1	3	
	SAGADAHOC	5,667	1	3	
	LINCOLN	519	1	3	
	KNOX	744	1	3	
	WALDO	168	1	3	
	HANCOCK	0	1	3	
	WASHINGTON	0	1	3	

Table 3-7. Summary of Storm Surge Exposure Model

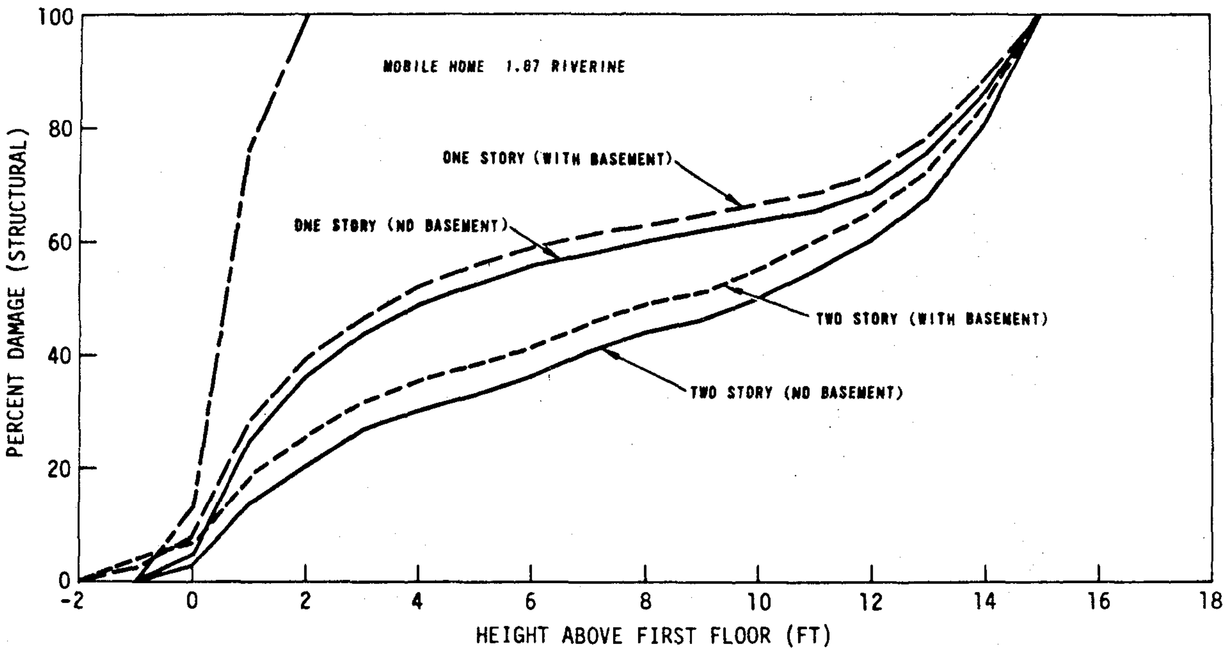


Figure 3-28. Typical Storm Surge Depth versus Damage Curves (Heavy Wave Action)

The risk model uses the hazard, exposure, and vulnerability models to predict expected average annual losses from 1970 to the year 2000. For each county exposed to the storm surge hazard, the annual probability of different surge heights are applied to the exposed population and expected damages calculated from the damage curves and the vulnerability model.

Tsunami

Although tsunamis have been recorded in the Atlantic Ocean and Carribean Sea, only one or two since the European Settlement began have ever caused any damage to the eastern edge of the North American continent. One struck Puerto Rico in 1918 and another, the eastern coast of Canada in 1929 [Ayre, 1975]. We therefore know that the average annual risk is very small; however, an exact quantification of it will require a much longer data base than is currently available. Consequently, the damage estimates developed herein have concentrated strictly on the Pacific Basin. A summary of the risk of damage assessment procedure is presented in Figure 3-29.

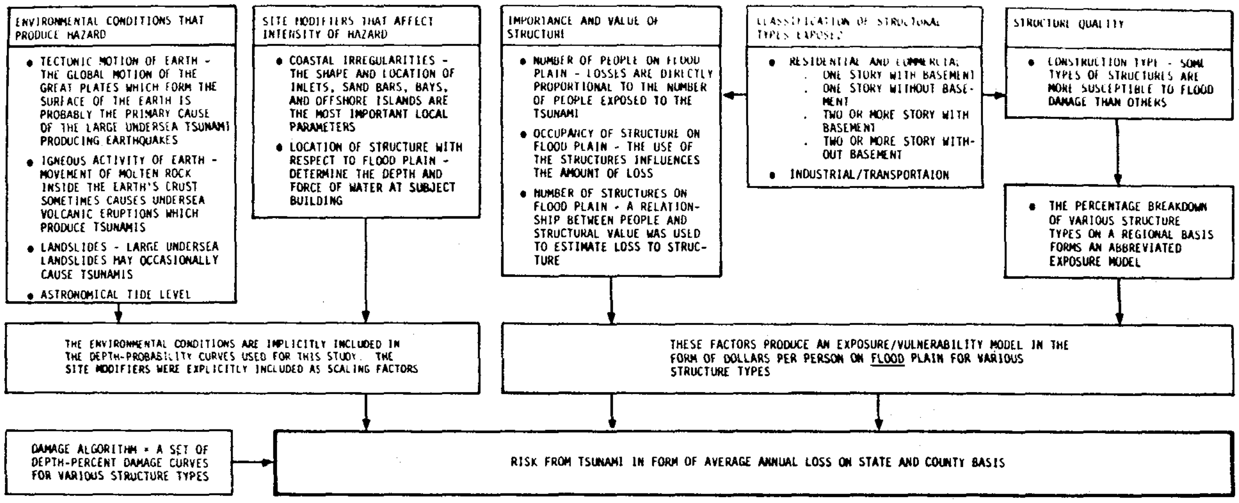


Figure 3-29. Tsunami Risk Determination Procedure

Both the hazard and exposure estimates are organized on a community basis. A list was compiled of all recognizable communities, incorporated and unincorporated, along the Pacific Coast of the United States. Hazard parameters were then generated for each listed community. Likewise, an exposure estimate was developed for each community. The results generally show that the critical item in the determination of average annual damage is the exposure model (i.e., the number of people exposed to tsunami) and not the hazard model.

The hazard model for tsunami is similar to the storm surge model. A plot of run-up height versus return period or annual probability of occurrence is prepared for each community. These relationships are illustrated in Figure 3-30.

The following discussion provides a general description of the tsunami hazard and exposure vulnerability relationships. The areas of investigation include: the coastlines of California, Oregon, and Washington; the southern coastline of Alaska (including the Aleutian Islands); and the Hawaiian Islands. The counties within these states experiencing exposure to the tsunami hazard are listed in Table 3-8.

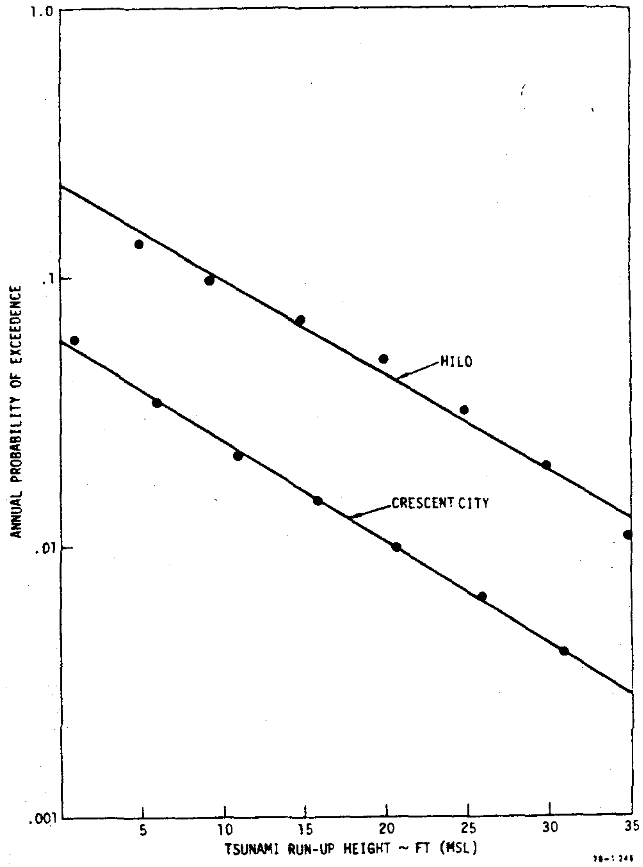


Figure 3-30. Typical Tsunami Run-Up/Frequency Relationships

CALIFORNIA

- SAN DIEGO
- ORANGE
- LOS ANGELES
- VENTURA
- SANTA BARBARA
- SAN LUIS OBISPO
- MONTEREY
- SANTA CRUZ
- SAN MATEO
- SAN FRANCISCO
- ALAMEDA
- CONTRA COSTA
- SOLANO
- MARIN
- SONOMA
- MENDOCINO
- HUMBOLDT
- DEL NORTE

OREGON

- CURRY
- COOS
- DOUGLAS
- LANE
- LINCOLN
- TILLAMOOK
- CLATSOP

HAWAII

- HAWAII
- HONOLULU
- KAUAI (INCL. KAUAI, NIHAU ISLANDS)
- MAUI (INCL. MAUI, MOLOKAI, LANAI ISLANDS)

ALASKA

- OUTER-KETCHIKAN
- KETCHIKAN
- PRINCE-OF-WALES
- WRANGELL-PETERSBURG
- SITKA
- ANGOON
- JUNEAU
- SKAGWAY-YAKUTAT
- HAINES
- CORDOVA-McCARTHY
- VALDEZ-CHITINA-WHITTIER
- SEWARD
- KENAI-COOK INLET
- ANCHORAGE
- MATANUSKA-SUSITNA
- KODIAK
- ALEUTIAN ISLANDS
- BRISTOL BAY
- BRISTOL BAY BOROUGH
- BETHEL
- WADE HAMPTON
- NOME

WASHINGTON

- WAHKIAKUM
- PACIFIC
- GRAYS HARBOR
- JEFFERSON
- CLALLAM
- KITSAP
- ISLAND
- PIERCE ISLAND
- KING
- SNOHOMISH
- SKAGIT
- SAN JUAN
- WHATCOM

Table 3-8. Tsunami Study - Counties Covered

The primary data source for the hazard model for the coterminous United States was the work performed by Houston and Garcia [1974, 1975]. This work is not based on historical runup data, since little exists, but on an inductive approach, using postulated source characteristics and propagation models. Only tsunamis of distant origin were considered, since the California coastal area does not have the characteristics of known tsunami-generating regions. Detailed height/frequency relationships [Figure 3-30] were obtained for Hilo, Hawaii [U.S. Army Corps of Engineers, 1966], and Crescent City, California [California Office of Emergency Services, 1972]. The Hilo curve formed the basis for the hazard intensity assessment in Hawaii and the Crescent City curve formed the basis for much of Alaska. The uncertainty in the tsunami depth-probability relationships is estimated to range from ±40 percent to ±75 percent.

The exposure model for tsunami was developed following four basic steps:

(1) Determine (wherever possible and from whatever source available) an inundation area for the 100-year and/or the 500-year events.

(2) Assume a linear relationship between inundation area and tsunami height so that an inundation area can be associated with any return period.

(3) Determine the population density of the inundated area using a relationship between city size and density and data (where available) on the specific type of land use present.

(4) Limit the exposure at low elevations but providing that there be no structures exposed below the nearest integer height above the spring tide height (all heights measured from mean sea level, MSL).

There were 191 separately identifiable communities in California, 80 in Oregon, 182 in Washington, 197 in Alaska, and 147 in Hawaii that were catalogued as being potentially subject to tsunami.

Inundation area for approximately 78 percent of the communities potentially subject to tsunami were developed. In many cases, this area was determined to be zero.

Fourteen different sources [See Lee, et. al., 1976] were used to estimate inundation areas. Most data souces provided maps which outlined inundation areas associated with specific recurrence intervals. These areas were measured to quantify the size of the inundation area. When inundation areas were not already defined, topographic maps were utilized. In these cases, the inundation area was defined as that area laying between the shoreline and the elevation contour equal to the tsunami recurrence height.

As for the other water related hazard, the tsunami damage relationships consist of a set of depth-damage curves. The structural categories are similar to those used for storm surge, except for the expansion of industrial buildings to include port facilities.

Depth-damage curves developed by the Corps of Engineers [1966], were available for one and two-story residential structures without basements. This data together with the Federal Insurance Administration curves for riverine flooding [Grigg, et. al., 1975] formed the basis for the depth-damage curves [Figure 3-31] adopted for this study.

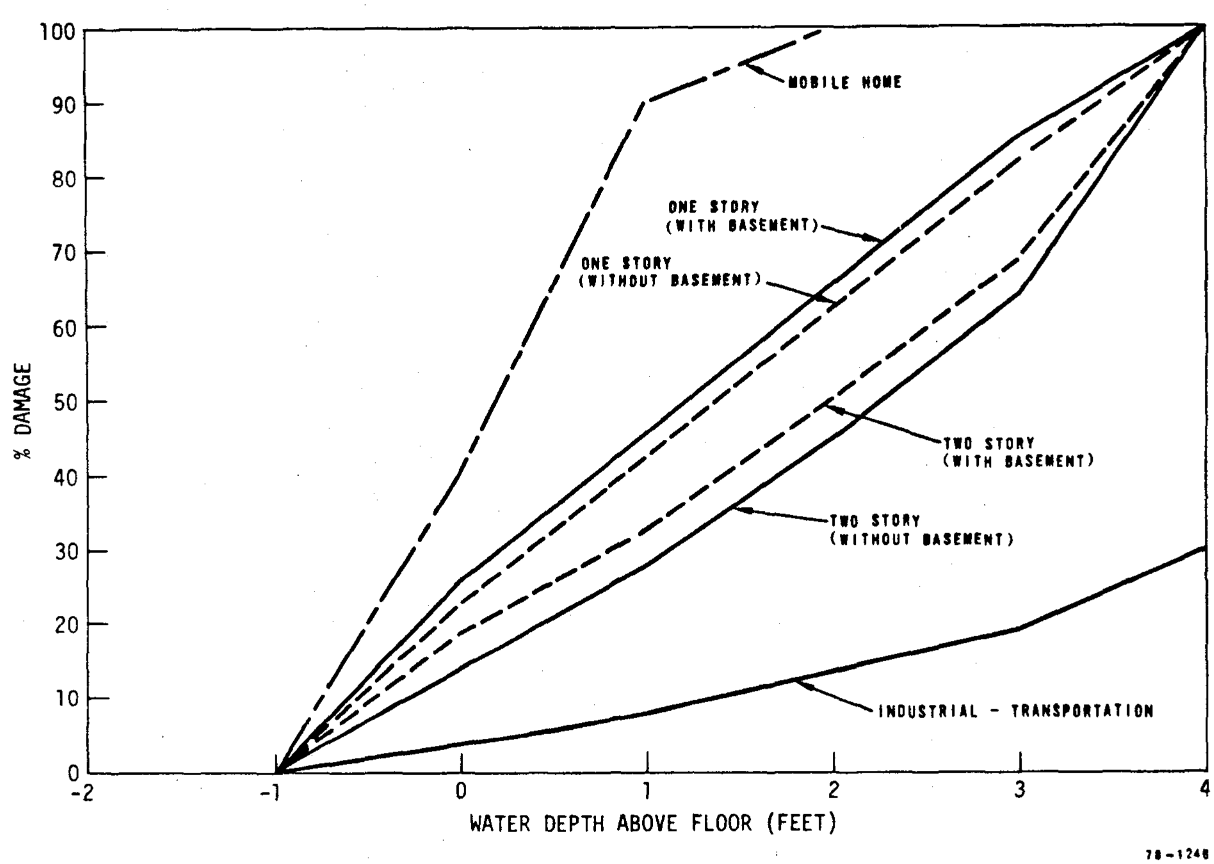


Figure 3-31. Tsunami Depth Damage Relationships

Since only limited data is available on tsunami depth-damage relationships, engineering judgement was a fundamental component in the development of these damage curves.

The risk model uses the hazard, exposure and vulnerability models to estimate expected average annual losses for the year 1970 to the year 2000. For each county, as well as for each community within that county, the annual probability of different tsunami heights was applied to the exposed population and expected damages were calculated using the damage curves and the vulnerability model.

Wind Hazards

The wind hazards considered in this study are tornadoes, hurricanes, and severe winds. Tornadoes and severe winds occur in every state of the United States while the hurricane problem is confined primarily to the Gulf and Atlantic Coast areas.

The principal difference in the risk determination procedure between the three wind hazards is in the assessment of the intensity of the occurrence of the hazard. The same exposure-damage relationships were used for all three hazards. The following discussion explains the differences in the hazard models and describes the exposure-damage relationships and risk procedure. A complete discussion of the models developed for this study is contained in a report entitled; "Natural Hazards: Tornado, Hurricane, Severe Wind Loss Models", by Hart [1976].

Tornado

Although a tornado is a complex meteorological system with as yet no universally accepted description, the distribution, occurrence, and intensity for these phenomena have been fairly well established. The risk determination procedure used for the tornado analysis is described in Figure 3-32.

Numerous authors have studied this complex phenomenon, but two are particularly applicable to this work because of their convenient data format. Thom [1963] and Pautz [1969] performed similar studies of tornado occurrence and intensity during the years 1955-1967. Both authors used a 1° by 1° regionalization for tornado occurrence. The total number of tornadoes recorded by these authors in each cell for the period from 1955 to 1967 are shown in Figure 3-33.

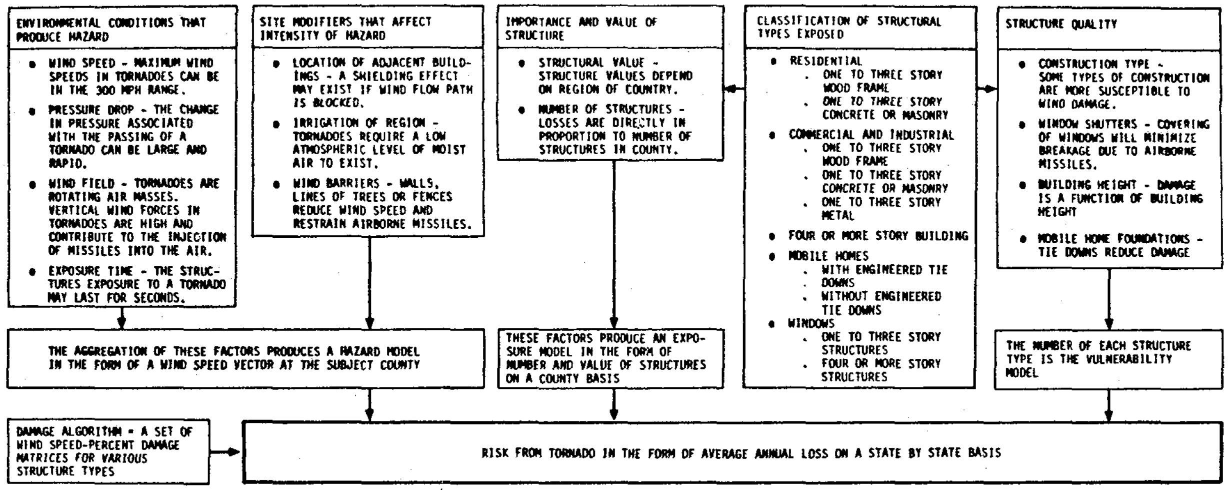


Figure 3-32. Tornado Risk Determination Procedure

The environmental conditions which produce tornadoes and the site modifiers which affect their intensity are many and they are inter-related in very complex ways. The dominant characteristic of a tornado, however, is the maximum wind speed. Fujita [1970] developed a sub-classification whereby tornadoes are classified by their maximum wind speeds. His classification categories were used for this study [Table 3-9]. It was also assumed that the probability of a tornado striking an area is uniform over each 1° by 1° geographic grid. Thus, each county in the United States was assigned the tornado probability for the 1° grid in which its county seat is located [Figure 3-33]. Risk of damage was estimated utilizing the Thom and Pautz data bases for tornado occurrence and the tornado intensity distribution shown in Table 3-9.

WIND STATE	FUJITA CLASSIFICATION	MAXIMUM WIND VELOCITY (MPH)	PERCENT OF OBSERVED TORNADOES IN CLASSIFICATION
1	-	-	not applicable to tornado
2	F0	40 - 72 (56)*	19.9**
3	F1	73 - 112 (93)	44.0
4	F2	113 - 157 (135)	26.6
5	F3	158 - 206 (182)	7.2
6	F4	207 - 260 (234)	2.1
7	F5	261 - 318 (290)	0.2

* simple average wind speed; wind speeds are at 1/4 mile
**[Fujita and Pearson, 1973]

Table 3-9. Fujita Classification and Tornado Occurrence

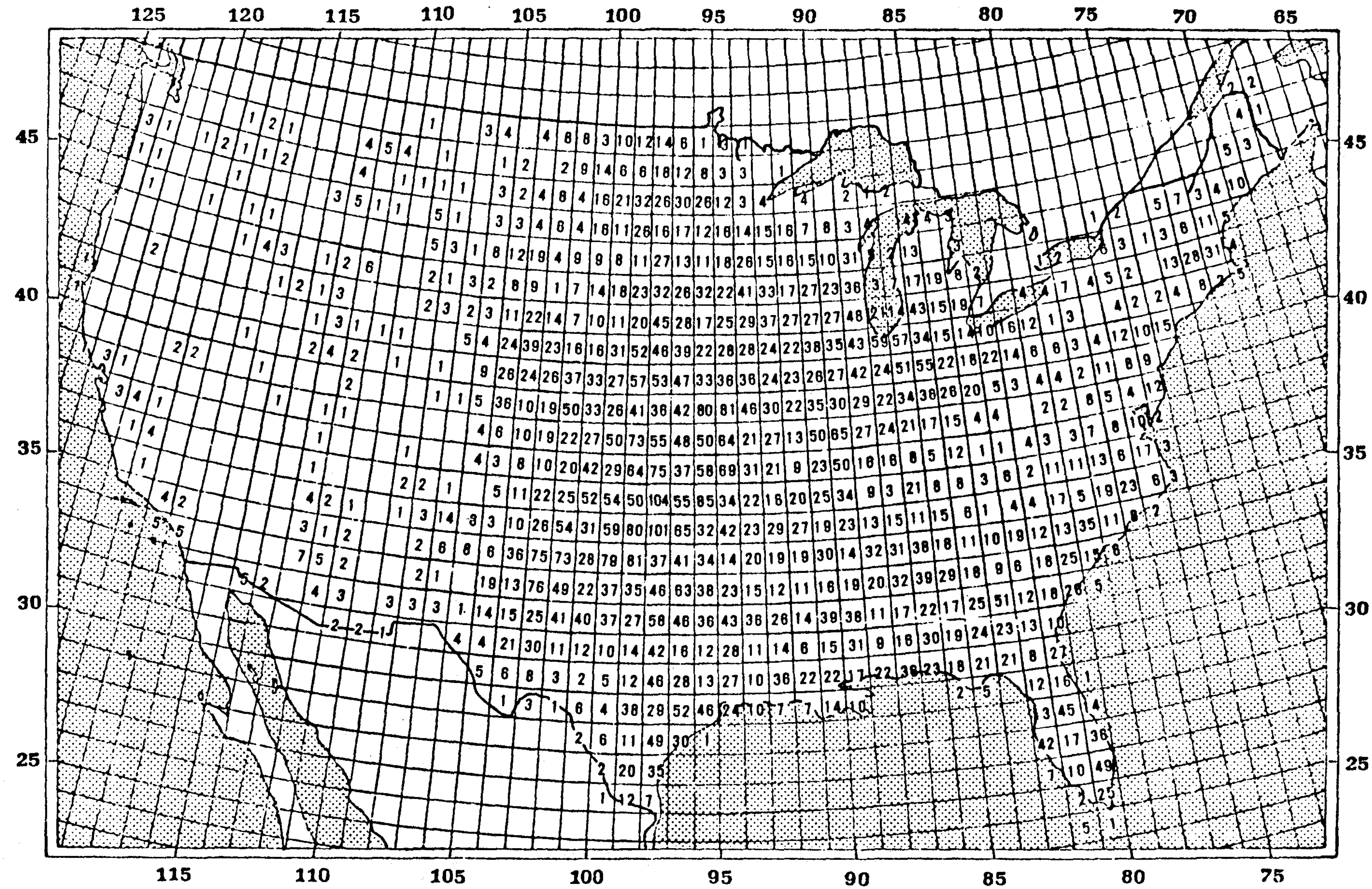


Figure 3-33. Tornadoes in 1° by 1° Grid Cells Throughout the U.S. [U.S. Department of Commerce (ESSA, Pautz, 1969)]

Hurricanes

Hurricanes are large cyclonic storms with wind velocities in excess of 73 miles per hour. Although hurricanes differ from tornadoes in the following respects, the risk associated with them can be determined in a similar fashion (Figure 3-34).

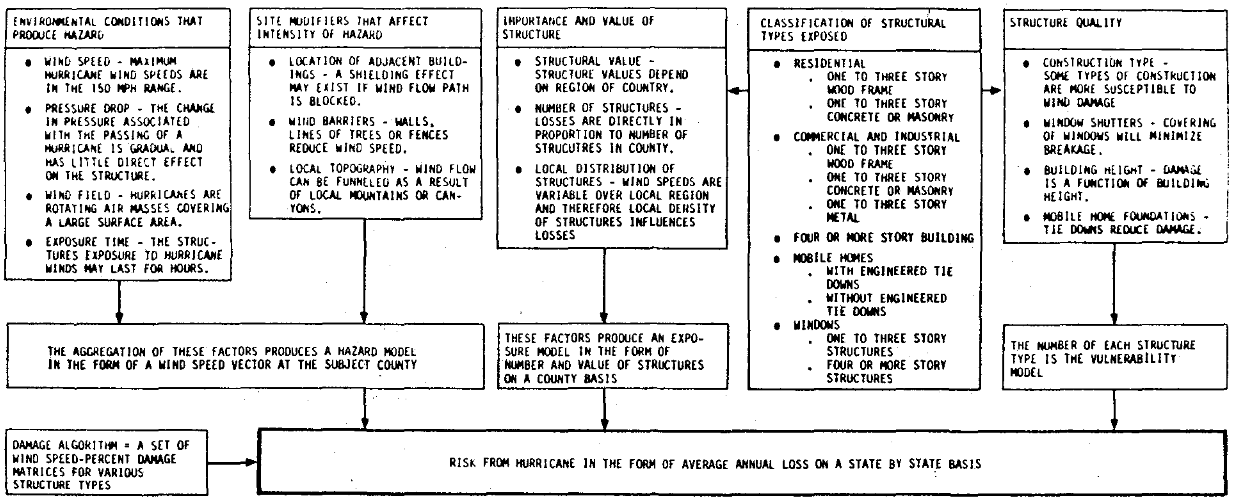


Figure 3-34. Hurricane Risk Determination Procedure

1) Hurricane maximum wind speed is usually less than that of a tornado.
2) The rotating hurricane air mass covers a much greater land area than a tornado.
3) The lifetime of a hurricane is measured in days, whereas a tornado is measured in minutes or hours.
4) The pressure differential associated with a hurricane is more gradual than that associated with a tornado.
5) Hurricanes are less prone to carry heavy missiles than are tornadoes due to the lower wind speeds.

Utilizing an extreme wind speed model proposed by Thom [1968], a 1° by 1° grid was overlaid on the coastal area of the United States where hurricane winds occur. Utilizing Thom's wind speed maps, it was possible to establish the probability of hurricane winds occurring at varying wind speeds for each grid cell and thus each county. The maximum wind speed ranges and the representative wind speed for each wind state is presented in Table 3-10. As with tornado, the probability of occurrence is assumed to be uniform over the entire 1° per square grid cell.

WIND STATE	REPRESENTATIVE WINDSPEED (MPH)	RANGE OF WINDSPEED (MPH)
1	75	73.0 - 87.5
2	100	87.5 - 112.5
3	125	112.5 - 137.5
4	150	137.5 - 175.0
5	200	175.0 - 225.0
6	250	225.0 - 275.0
7	300	275.0 - 325.0

Table 3-10. Hurricane Representative Windspeeds and Corresponding Windspeed Range

Severe Winds

Severe winds ranging in speed up to 150 mph are common to all states. The risk determination procedure for severe winds [Figure 3-35] is similar to the other wind hazards.

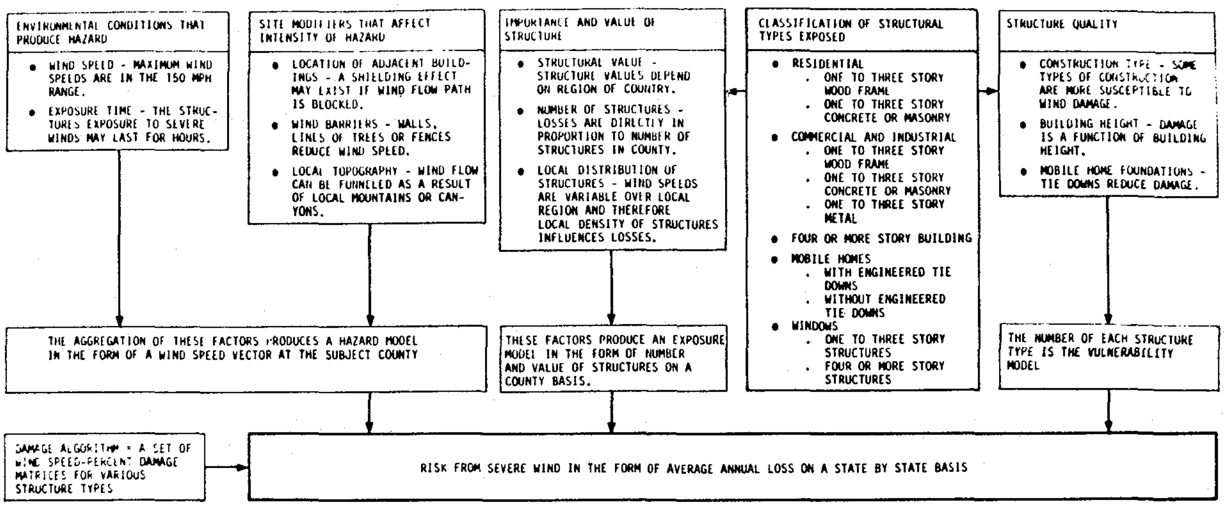


Figure 3-35. Severe Wind Risk Determination Procedure

Thom [1968] developed an extreme wind characterization of the United States. However his wind speed maps are not appropriate for damage estimation because they are based only on the single most severe wind speed each year. Therefore, the occurrence statistics for severe winds based on maximum hourly wind speed observations and maps developed by Valley [1965] were adapted in this study. A model of this type allows for the probability of the occurrence of multiple severe winds in any single month.

For this study, severe winds are assumed to be uniform over the 1° by 1° grid as was done for both tornadoes and hurricanes. Although this uniformity is not always true, a severe wind micronization is not warranted, or practical, for a broad damage estimation such as this.

Exposure-vulnerability Relationships

The degree of damage which can be expected for a building exposed to a particular wind state depends on the type of construction [Hart, 1976]. Consequently, eight separate structural categories were considered:

- One-to-three story wood frame residential
- One-to-three story wood frame commercial, financial and service
- One-to-three story concrete and masonry wall, residential
- One-to-three story metal commercial, financial and service
- One-to-three story concrete and metal commercial and industrial
- Four-or-more story steel ductile frame
- Mobile homes with engineered tie-downs
- Mobile homes without engineered tie-downs

In addition, two categories of wind characteristics were examined to estimate window damage. These are: windows in structures of less than four stories and windows in structures of four or more stories.

Structure type, structure value, numbers of structures, and the distribution of structures, all determined on a county basis provide the exposure model used to assess the risk of buildings to wind hazards. Damages were calculated for each of the building and window categories using a wind state-percent damage matrix [Hart, 1976].

Utilizing the probabilistic wind speed intensity grids developed for each wind type, the damage matrices and estimates of the United States building population, it was possible to estimate the risk (i.e., average annual loss) for each state or county.

The quantitative description of damage resulting from wind is of significant engineering importance and can lead to new design requirements which provide more wind resistant structures. There is, however, a shortage of quantitative knowledge concerning the relationship between wind damage and wind velocities [Hart, 1976]. It appears that an analytical prediction of building damage under a specific wind state is not within the present state of the art. It was necessary, therefore, to develop a means to relate wind state (i.e., speed) to damage percentage. The damage matrix approach developed by Whitman [1974] for quantifying earthquake damage was found to be applicable. Damage matrices were developed for each structure type and for windows. A panel of wind engineering experts was asked to estimate the probable degree of damage as a function of wind speed for each structure type. These data then were combined to produce a set of probabilistic damage matrices. A typical percent damage versus wind speed plot is presented in Figure 3-36. These curves represent average damage and are indicative of how a large sample of structures would be damaged when subjected to winds of varying intensities.

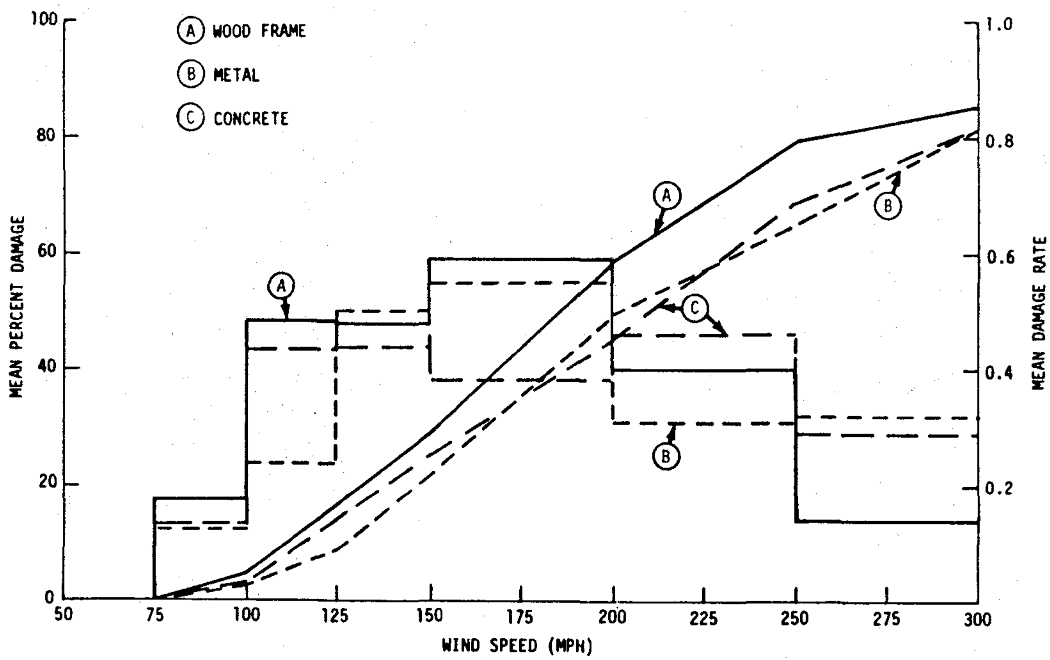


Figure 3-36. Typical Mean Damage Versus Wind Speed

Cost Analysis Methods

For each hazard, a set of possible mitigations was identified and estimates of mitigation-related damage reductions were prepared. For most of these mitigations, the investment costs associated with application of the mitigation were determined. These estimates were expressed either as unit costs (viz. cost to provide fifty-year-flood protection to one community, cost to floodproof one single family dwelling unit) or as a percent of the value of the structure(s) to which the mitigation was intended to be applied. Typically, these data then were utilized to calculate fifty-year annual amortized mitigation costs over a range of interest rates. The rates of annual mitigation costs to annual dollar loss reductions predicted for the mitigation then was determined and annual net savings (annual amortized mitigation costs minus annual loss reduction) were calculated. Also, for all hazards, the building-life projections of "net savings" have been discounted over a range of appropriate rates.

Mitigation Cost Estimates

Estimates of mitigation costs were developed through use of data presented by the Naval Facilities Engineering Command [1973], Carson [1975], U.S. Corps of Engineers [1975], Leslie and Biggs [1972], Godfrey [1977], Federal Insurance Administration [1976], and Structural Engineers Association of California (SEAOC) [1970]. All estimates include the cost of both labor and materials. Since some of the source data were available only to specific regions, all cost data have been adjusted to account for the regional differences in construction costs which are depicted in Figure 3-37.

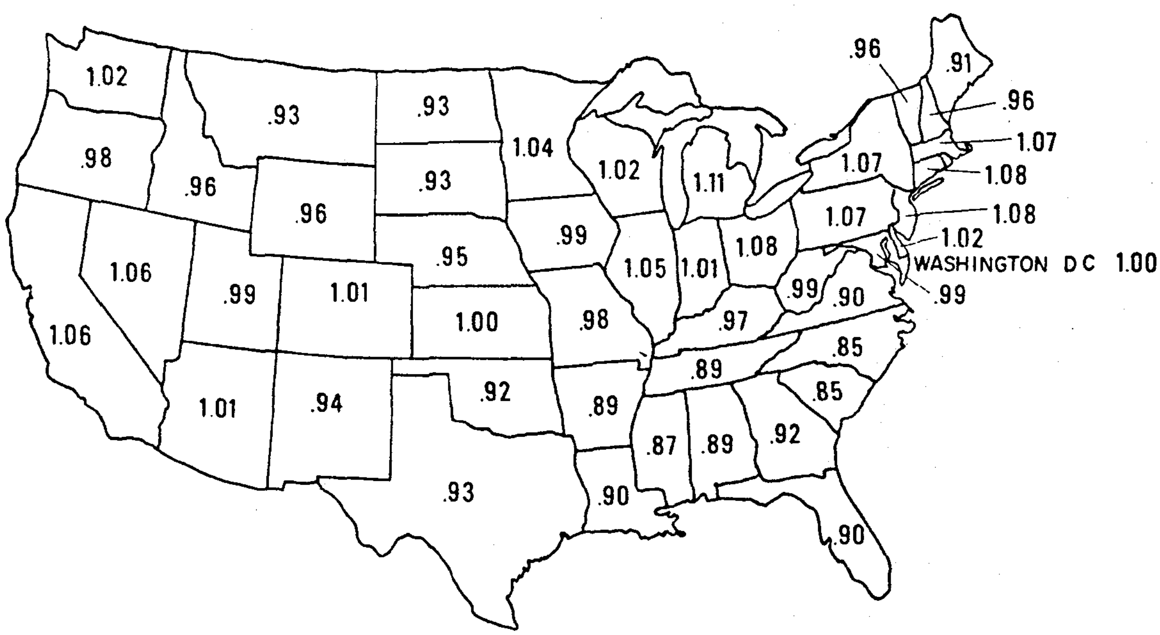


Figure 3-37. Map of Continental United States Showing Geographic Cost Factors

Earthquake Mitigation Cost Data

Cost estimates were developed for the following earthquake mitigations:

- Modifying or designing structural and non-structural systems to UBC Seismic Zone 1;
- Modifying or designing structural and non-structural systems to UBC Seismic Zone 2;
- Modifying or designing structural and non-structural systems to UBC Seismic Zone 3;
- Modifying or designing structural and non-structural systems to UBC Seismic Zone S; (2x UBC Zone 3)
- Modifying or designing non-structural systems to UBC Seismic Zone 1;
- Modifying or designing non-structural systems to UBC Seismic Zone 2;
- Modifying or designing non-structural systems to UBC Seismic Zone 3;
- Modifying or designing non-structural systems to UBC Seismic Zone S; (i.e., 2x UBC Zone 3)

Non-structural systems are defined as those elements of a building that are not integral to its construction, such as the architectural treatment, mechanical and electrical facilities, partitions, glass panels, etc. Figure 3-38 provides estimates for existing and proposed high-rise structures based on a study performed by Leslie and Biggs [1972], and Figure 3-39 gives estimates for proposed low-rise structures based on the report by SEAOC [1970]. These estimates represent the percent increase over the total original costs. For high-rise buildings, estimates are provided for reinforced concrete structures (frame + non-structural) and steel structures (frame + non-structural). The higher costs shown for reinforced concrete structures are a result of several factors: 1) higher design, detailing, and placing cost for a structurally more complicated resisting frame; 2) stringent design criteria (ductile, seismic resistant structures); 3) for an equal volume structure, a concrete structure is more stiff than a steel structure and so attracts higher seismic design forces. From Figure 3-39 the highest cost increases are reported to be for concrete block buildings. As a matter of fact, these structures are highly unsuited for high lateral forces and as a result, they need extensive reinforcing.

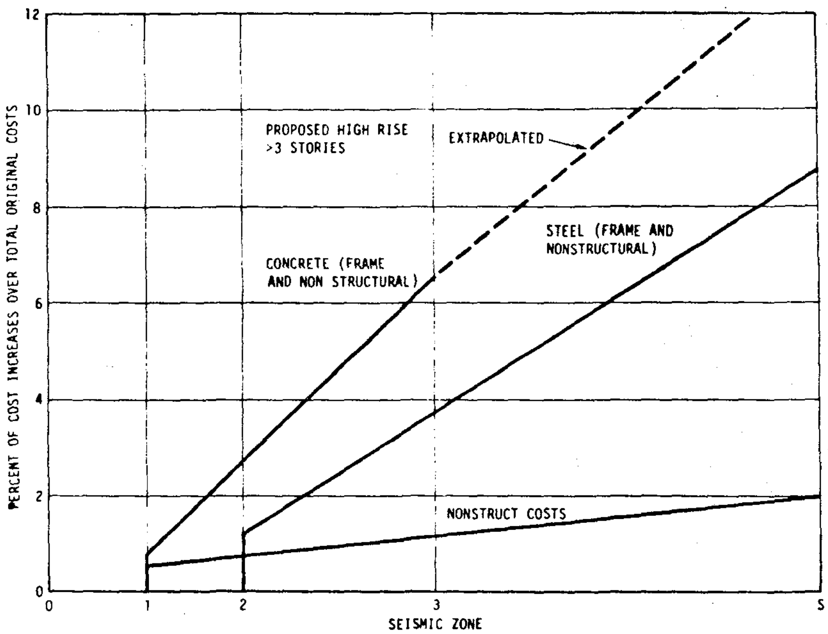


Figure 3-38. Earthquake Cost Data - High Rise [Leslie, 1972]

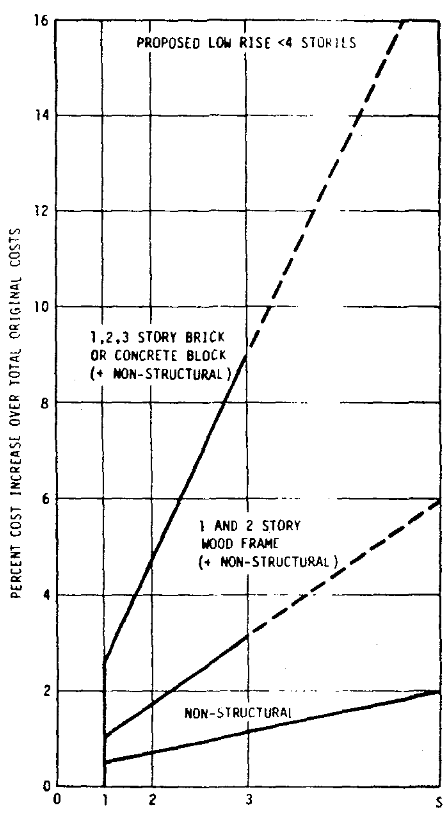


Figure 3-39. Earthquake Cost Data - Low Rise [SEAOC, 1970]

It should be mentioned that the cost estimates assume that the original structure is of quality design and meets minimum code design (wind forces), and that the structural design for each seismic zone is the most economical for the given force constraints. The curves are not based on increasing the lateral force-resisting system that was adequate for the wind loads. Rather, the cost curves include the change of frame type to accommodate changing force constraints (e.g., change from non-ductile reinforced concrete vertical load frame in Zone 1 to a ductile reinforced concrete moment-resistant frame in Zone 3).* Mitigation costs (as percent of building value) for modification of existing structures are assumed to be eight times those identified above.

Wind Mitigation Cost Data

Cost estimates were developed for building strengthening measures capable of yielding UBC wind resistance ratings, as indicated:

STRUCTURAL CLASSIFICATION	STRUCTURAL DESIGN LEVEL
One-to-three story residential Wood Frame	0.75, 1.0, 1.5, 3.0 UBC
One-to-three story residential Concrete or Masonry	0.75, 1.0, 1.5, 3.0 UBC
One-to-three story commercial Wood Frame	0.75 UBC
One-to-three story commercial Concrete or Masonry	0.75 UBC
One-to-three story commercial Metal (non-steel)	0.75 UBC
Four-or-more story, Concrete or Masonry	0.75 UBC
Four-or-more story, Concrete Shear Wall	0.75 UBC
Steel Frame, regardless of height	0.75 UBC
Mobile Home	UBC

*Note that all cost curves in Figures 3-38 and 3-39 are for proposed buildings. Since the cost of modifying an existing structure to the foregoing levels is considerably higher than that for a proposed structure, the percent increase is multiplied by a factor of 8 to obtain cost factors for existing structures.

The cost estimates presented in Figures 3-41 and 3-42, for high-rise and low-rise structures, were derived from those presented for earthquake using the relationship of Figure 3-40. It relates the UBC Seismic Zones to the UBC wind loads based on identifying the UBC levels for the two categories which have the same base shear force on which the Building Code is based. The upper and lower abscissa of Figure 3-40 shows this relationship.* The data points (represented by Δ) were taken from SEAOC [1970] and represents the percent cost increase in designing a one-, two-, or three-story brick or concrete block building to the various design levels excluding the non-structural part. The data point for seismic Zone 2 cost was developed under the assumption that for areas located in Zones 0, 1, and 2, the percent increase over the original cost is 4 percent, as reported in Figure 3-39, where the non-structural elements are also taken into account. The point for Seismic Zone 3 cost was developed under the assumption that for areas which do not presently enforce the UBC design for hurricane, tornado, severe wind, or earthquake, the percent increase over the original cost to meet Zone 3 requirements would be 9 percent. If the area does not enforce the UBC design requirements for wind, then the increase to meet Zone 3 requirements is only 4 percent. The curves in Figures 3-41 and 3-42 are the same as those in Figures 3-38 and 3-39 (used for the earthquake cost data), but now the abscissa have been changed to introduce the wind loads.

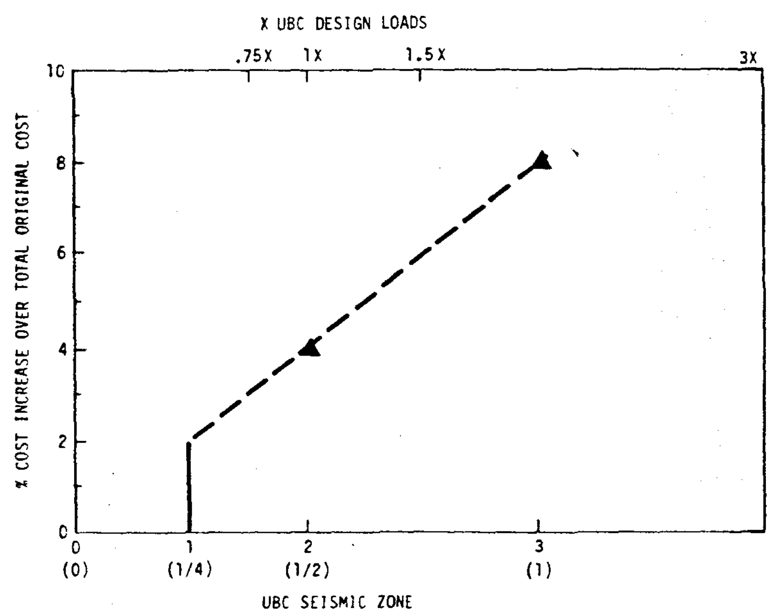


Figure 3-40. The Relationship Between Cost Factors for Wind Loads and Seismic Zones of the Uniform Building Code (UBC)

*This relationship has been introduced to determine the wind cost factors from the earthquake cost factor.

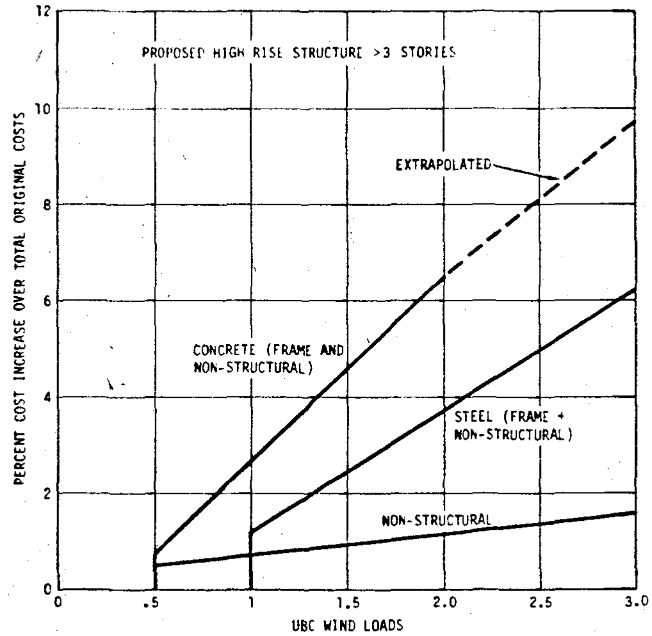


Figure 3-41. Wind Cost Data - High Rise

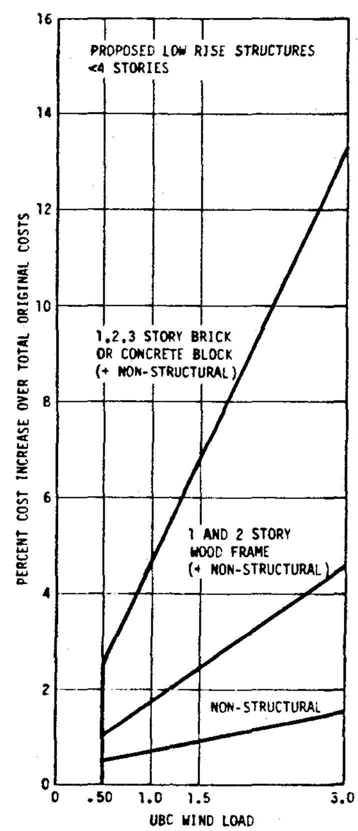


Figure 3-42. Wind Cost Data - Low Rise

As with the earthquake data, the percent increase for a proposed building is multiplied by a factor of 8 to get the cost (as a function of replacement value) of modifying an existing building.

Note that, in working the comparison between UBC Seismic Zone and UBC Wind Loads, we consider the effectiveness of the mitigations to be the same for the two types of hazards. Only under this assumption can the wind mitigation cost data be considered to be reliable.

The cost of anchoring a mobile structure was found to be approximately $500 per unit from a telephone survey of several mobile home dealers.

The cost of strengthening windows for wind loading was found to be $0.62 per sq. foot from Building Construction Cost Data [1972]. Overall, the percent cost increase over the original cost is about 75% higher for concrete than for steel structures in high-rise buildings, and about 200% higher for brick or concrete than it would be for wood frame structures for low-rise buildings.

Flood Mitigation Cost Data

Cost estimates were developed for two classes of mitigations: (1) floodproofing to exclude water (for residential and commercial structures); (2) elevating building (on "fill" and "other than fill") for masonry, wood frame and wood frame on slab foundation. The cost data are summarized in Figures 3-43 through 3-45. These figures are a very rough approximation of data provided in Carson [1975], F.I.A. [1976], and U.S. Army Corps of Engineers [1975], using an assumed baseline construction cost of $25/sq. ft.; the reason for doing this is to normalize the data that is given for particular samples for which this analysis was performed. Figure 3-43 shows the percent increase in cost at different levels of mitigation, represented as flood height protection for residential structures excluding wood frame buildings. It shows that floodproofing structures with basements would cost 3.50 times the same mitigation applied to structures without the basement. For commercial buildings the difference drops to 0.60 times [See Figure 3-44].

Figure 3-45 summarizes the costs of elevating structures through means other than fill, usually through pilings or walls. The increasing cost for this

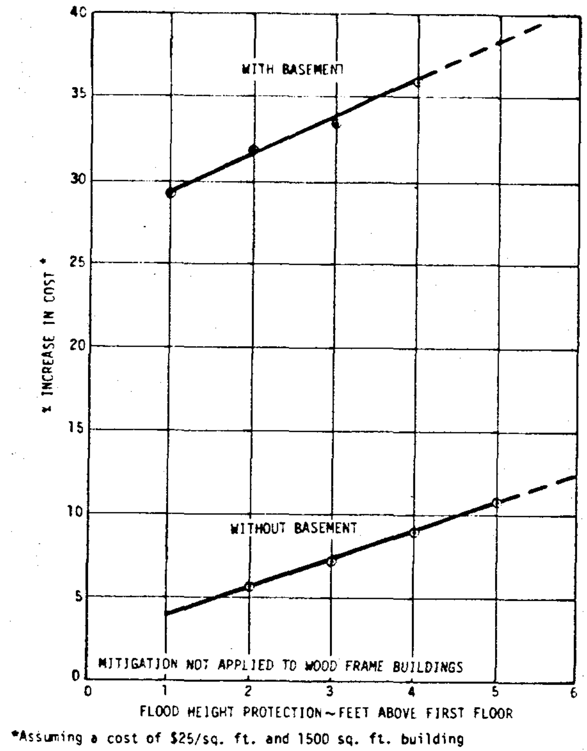


Figure 3-43. Floodproofing to Exclude Water - Residential [W.D. Carson, 1975]

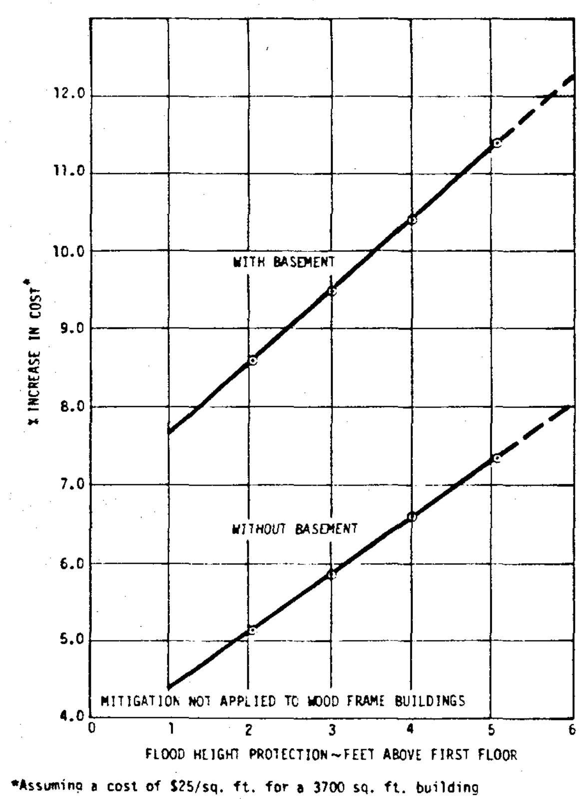


Figure 3-44. Floodproofing to Exclude Water - Commercial [W.D. Carson, 1975]

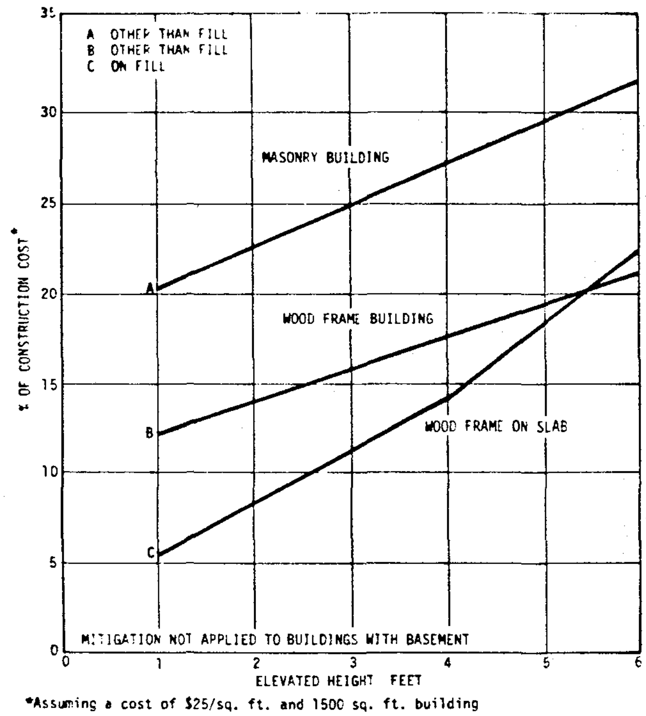


Figure 3-45. Elevating Building [F.I.A., 1976, U.S. Army, 1975]

mitigation is 60% more for masonry buildings than for wood frame buildings, mainly due to the higher weight of masonry structures. An average decrease of 70% is obtained when passing from "raising by means other than fill" to "raising on fill" up to 4 feet.

At higher levels there is a more pronounced increase of costs of elevation on fill because the initial construction costs for foundation and walls in the A and B type of mitigation (see Figure 3-45) are amortized for higher elevations.

National Average Cost Factors

Tabular expressions of the cost curves presented above are depicted in Tables 3-11, 3-12, and 3-13.

	PROPORTION	1.5 UBC	3.0 UBC
CONCRETE +3 STORIES	25.42%	.031	.060
STEEL +3 STORIES	25.42%	.025	.062
BRICK RESIDENTIAL 1-3 STORIES	8.05%	.033	.095
WOOD FRAME RESIDENTIAL 1-3 STORIES	41.05%	.010	.030
AVERAGE COST FACTOR		.021	.051

Table 3-11. National Average Wind Building Code Cost Factors

	PROPORTION	ZONE 3	2X ZONE 3
CONCRETE +3 STORIES	25.42%	.038	.130
STEEL +3 STORIES	25.42%	.027	.088
BRICK RESIDENTIAL 1-3 STORIES	8.05%	.065	.180
WOOD FRAME RESIDENTIAL 1-3 STORIES	41. 05%	.020	.060
AVERAGE COST FACTOR		.030	.095

Table 3-12. National Average Earthquake Building Code Cost Factors

FLOOD PROOFING	PROPORTIONS	2 FT. PROTECTION	4 FT. PROTECTION
RESIDENTIAL WITH BASEMENT	27.52%	.333	.373
RESIDENTIAL WITHOUT BASEMENT	27.08%	.053	.093
COMM. & IND. WITH BASEMENT	25.82%	.074	.103
COMM. & IND. WITHOUT BASEMENT	22.58%	.038	.066
AVERAGE COST FACTOR		.132	.166
ELEVATION	PROPORTIONS	2 FT PROTECTION	4 FT PROTECTION
MASONRY	16.40%	.227	.272
WOOD FRAME	17.73%	.139	.176
WOOD FRAME OR SLAB	65.87%	.083	.136
AVERAGE COST FACTOR		.117	.165

Table 3-13. National Average Storm Surge Building Code Cost Factors

Cost Feasibility Analysis

For each of the mitigations discussed above, "break-even" damage rates also were calculated [See Table 3-14]. Such a rate is defined as that building damage rate which must occur in an area if a hazard-specific mitigation is to produce annual loss reductions which are at least equal to the annual amortized cost of the mitigation.

Five values are necessary to determination of "break-even" damage rates: (a) the initial cost of the mitigation; (b) the annual expected loss reduction associated with the mitigation; (c) the period of time over which costs due to be amortized and loss reductions are to be experienced; (d) the total estimated loss reduction which will be produced by the mitigation over the lifetimes of buildings on areas to which the mitigation is applied; (e) either the discount rate which is to be applied to building-life loss reductions, or the building life accumulated annual amortized costs of the mitigation at a specified interest rate.

The "breakeven" damage rate therefore is that specific rate for a given hazard where the following relationship obtains:

$$\overline{DR}_{hrkl} = \frac{C_k}{(1+C_k)} \cdot \frac{1}{S_h - MS_h} \cdot \alpha_{ik}$$

where

$\overline{DR}_{hrkl}$ = the annual proportion of value lost due to the hazard, h, in the region, r, to structure type k, to wealth type l (building wealth)

C_k = the proportional increase in construction costs due to the mitigation on building type k

$(1+C_k)$ = the multiplier to determine new value of the building type, k, after mitigation

S_h = the portion of the annual structural losses saved due to the mitigation to hazard h

WIND HAZARDS COST/LOSS-REDUCTION RATIO	1.5 UBC COST FACTOR = 0.021	3.0 COST FACTOR = 0.051
4:3	0.0135	0.0218
1:1	0.0180	0.0290
4:5	0.0225	0.0362
2:3	0.0270	0.0434
4:7	0.0315	0.0506
1:2	0.0350	0.0580

EARTHQUAKE COST/LOSS-REDUCTION RATIO	ZONE 3 UBC COST FACTOR = 0.030	2X ZONE 3 UBC COST FACTOR = 0.095
4:3	0.0662	0.0587
1:1	0.0882	0.0782
4:5	0.110	0.0978
2:3	0.132	0.117
4:7	0.154	0.137
1:2	0.176	0.156

STORM SURGE COST/LOSS-REDUCTION RATIO	4 FT. ELEVATION OR FLOOD PROOFING COST FACTOR = 0.166	2 FT ELEVATION COST FACTOR = 0.117	2 FT. FLOOD PROOFING COST FACTOR = 0.132
4:3	0.0568	0.0392	0.0470
1:1	0.0757	0.0549	0.0627
4:5	0.0946	0.0706	0.0784
2:3	0.114	0.0863	0.0941
4:7	0.132	0.102	0.110
1:2	0.152	0.118	0.126

Table 3-14. Average Damage Rates Associated with A Range of Cost/Loss-Reduction Ratios for National Average Building Type Mix Assuming a Building Life of 50 Years and a Discount Rate of 6.1% (α=0.64)

α_{ik} = value based upon discount rate, building life, and building type

MS_h = the ratio of total economic losses to building losses for hazard h, nationally

Figure 3-46 shows the steps to compute the annual damage rate and the tables from which the variables can be obtained.

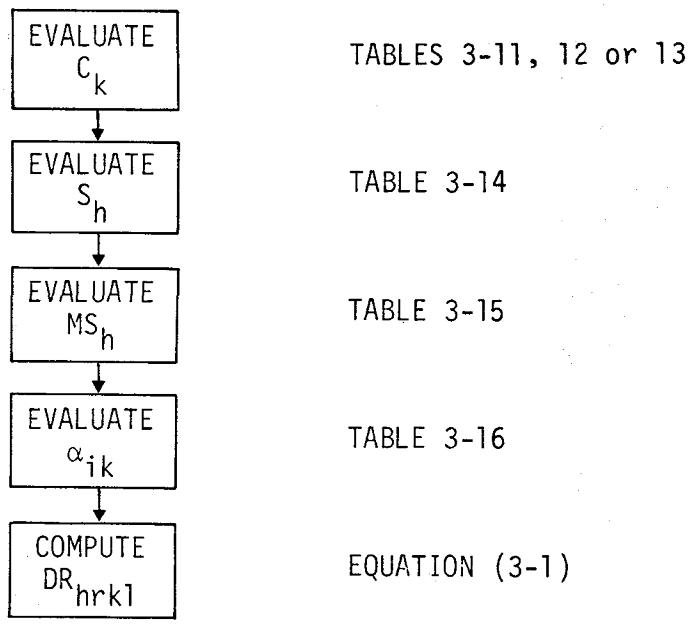


Figure 3-46. Steps in Computation of Annual Damage Rate

"Breakeven" damage rates were used in this study to identify counties in which specific mitigations might be considered to be cost feasible.

		1970 $ 10^6	RATIO MS_{1970}	2000 $ 10^6	RATIO MS_{2000}	MS AVERAGE
EARTHQUAKE	BUILDINGS	655.2	1.192	1177.0	1.320	1.256
	TOTAL	781.1		1553.7		
TORNADO	BUILDINGS	879.8	1.882	2058.0	2.536	2.209
	TOTAL	1656.0		5219.1		
HURRICANE	BUILDINGS	685.5	1.541	1742.0	2.024	1.782
	TOTAL	1056.0		3526.3		
SEVERE WIND	BUILDINGS	11.4	1.579	24.8	2.153	1.866
	TOTAL	18.0		53.4		
STORM SURGE	BUILDINGS	441.6	1.452	1176.0	1.992	1.722
	TOTAL	641.2		2342.9		
TSUNAMI	BUILDINGS	8.7	1.724	19.8	2.040	1.882
	TOTAL	15.0		40.4		
WIND AVERAGE	BUILDINGS	1576.7	1.731	3824.8	2.300	2.016
	TOTAL	2730.0		8798.8		

Table 3-15. The Ratios of Total Economic Loss to Building Loss

Discount Rates (i)						Building Lives (L)
0.0	2.9	6.1	10.0	15.0	20.0	
0.050	0.066	0.086	0.116	0.159	0.204	20.0
0.040	0.056	0.078	0.109	0.154	0.200	25.0
0.033	0.050	0.072	0.105	0.152	0.200	30.0
0.025	0.042	0.067	0.102	0.149	0.200	40.0
0.020	0.037	0.064	0.101	0.149	0.200	50.0
0.017	0.035	0.063	0.100	0.149	0.200	60.0
0.013	0.033	0.062	0.100	0.149	0.200	75.0
0.010	0.031	0.061	0.100	0.149	0.200	100.0

Table 3-16. Values of α Based on Different Discount Rates, and Building Lives

Analysis of Social Impacts

The impacts of natural hazards discussed to this point have been solely economic impacts which lend themselves to quantification for an overall picture of the effects of hazards on the population. However, there are other "social" impacts which also accompany the occurrence of natural disasters. The social impacts treated here do not comprise an exhaustive list, but rather they represent an attempt at a preliminary description of the pertinent social indicators that may provide insight for the decision maker in efforts to assess alternative mitigation procedures.

The first section discusses the method used for the estimation of life loss from the estimates of building damages incurred. Section two contains a description of the method employed in deriving the number of housing units lost. Also estimated is the average value of the loss per home. The third section deals with a measure of residential dislocation. This measure-homelessness-is determined by adding the time of inoperation and the occupancy to the housing unit loss estimate. The fourth section deals with the estimate of unemployment which results from income lossses. These unemployment estimates are another way of presenting the income losses and should not be interpreted as an additional economic impact.

Estimate of Mortality

The number of lives lost in an extreme natural event are represented in our model as a function of economic loss to buildings from that event. A relationship between damages (in constant 1970 dollars) and the number of lives lost was estimated from data available pertaining to past national disasters. This relationship was based on assumptions that: the dollar amounts of damage recorded for an event reflected only building damage, the lives lost were directly caused by the event, the vulnerability of the population was constant, and the value of all structures in all events was the same.

Dollar amounts of damage of past occurrences of natural hazards were supplied by insurance company records and include many types of damage (i.e., contents lossess). However, building losses which are not paid often go unnoted. For instance, most homeowner insurance policies for earthquake have a five percent deductible provision; thus, ceiling cracks and broken windows will generally not be reported by insurance companies. In addition, many businesses and homes are not insured for earth movement or earthquake damage.

The modeled mortality rate represents a simplification of the actual occurrence. Deaths may be partly related to the level of success of rescue operations as well as the level of physical destruction or structure characteristics. Population density, amount of warning, foreknowledge of the effects associated with the event, phychological impressions of the population, availability of shelter, and time of day of the occurrence certainly influence the number of casualties. No estimate of mortality can take into account all these factors.

A further complication in the construction of a life loss model is the relationship between value-at-risk and the value of potential losses. A disaster in an area with a high value of building wealth per person will incur greater economic loss per capital in a given event than in an area of lower wealth per capita. The inability to estimate the precise location of the event, especially for flood data, makes the differences in building value per person difficult to use as a parameter in a life-loss-to-monetary-loss relationship.

It has been noted in a variety of sources [Dacy and Kunreuther, 1969; U.S. Dept. of Commerce, 1972; National Bureau of Standards, 1974] that the relationship of deaths to pecuniary damage has a demonstrated trend over time. The choice of time as the single independent variable in the functional form of such a ratio may be weak but, having the relationship in this form is desirable and, as demonstrated in the data plots in Figures 3-47 and 3-48, a trend exists. The data are shown with a vertical scale of the logarithm (base 10) of the ratio LL/SD (life-loss to structural damage) plotted as a function of time from 1929 to 1970. To project forward this trend assumes that the data can be fitted by a quadratic function.

$$\log(LL/SD) = \alpha_1 + \beta_1(YR) + \beta_2(YR)^2 + \varepsilon$$

where α_1, β_1 and β_2 are coefficients to be determined, and ε accounts for the error in fit.

The results for hurricane and tornado are as follows:*

Hurricane: $\log(LL/SD) = 3.110 - .113(YR) - .000768(YR)^2$

or

$$(LL/SD) = 10^{\{3.110 - .113(YR) - .000768(YR)^2\}}$$

Tornado: $\log(LL/SD) = .245 + .035(YR) - .000613(YR)^2$

or

$$(LL/SD) = 10^{\{.245 + .035(YR) - .000613(YR)^2\}}$$

In projecting forward to the year 2000, both the choice of the model and the fit of the data influence the result. In this case it appears that it is possible that the projections are very uncertain and could vary by an order of magnitude.

The forecasts of deaths for storm surge and hurricane wind impacts are not distinguishable for estimation of separate life-loss relationships. Thus they are both assumed to be equally represented in the data. Flood losses were assumed to exhibit the same characteristics as those for storm surge. The 1970 forecast provided an estimate of the value of deaths per unit of economic loss for that year, removing the time bias; Figure 3-47 and 3-48 show plots of both the data and the estimated relationships. The estimates of life loss due to severe wind were also estimated from the tornado data, since no source of data dealt solely with severe wind. Since, by definition, no water-related deaths could be due to severe wind, the hurricane relationship is not applicable for this hazard. Consequently, for hurricane and storm surge .0956 deaths per million dollars damage, and for tornado and severe wind .488 deaths per million dollars damage, were used to calculate life loss estimates for the projected years. The death/damage ratio for tsunami was 2.432 deaths per million dollars of building damage and was

*The specifics of the regression fit are as follows:

	DEGREE OF FREEDOM	R^2	VARIANCE	STANDARD ERRORS OF THE COEFFICIENTS		
				σ_{α_1}	σ_{β_1}	σ_{β_2}
HURRICANE	38	.350	.367	1.339	.053	.000455
TORNADO	53	.645	.0876	.063	.158	.000504

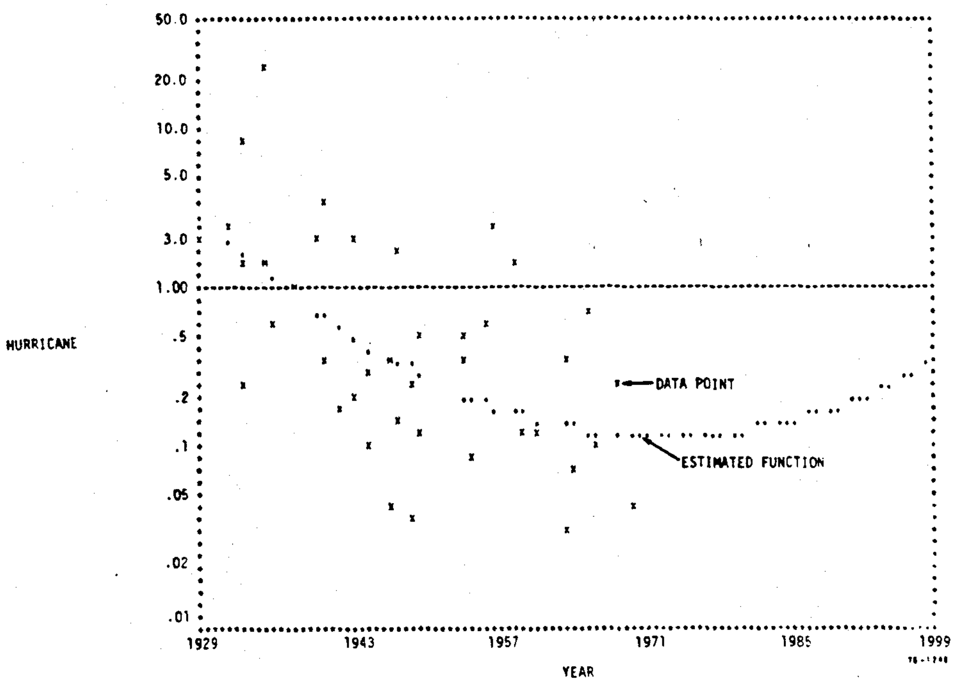


Figure 3-47. Plot of (Deaths/Million $ Damage) Due to Hurricane Versus Year

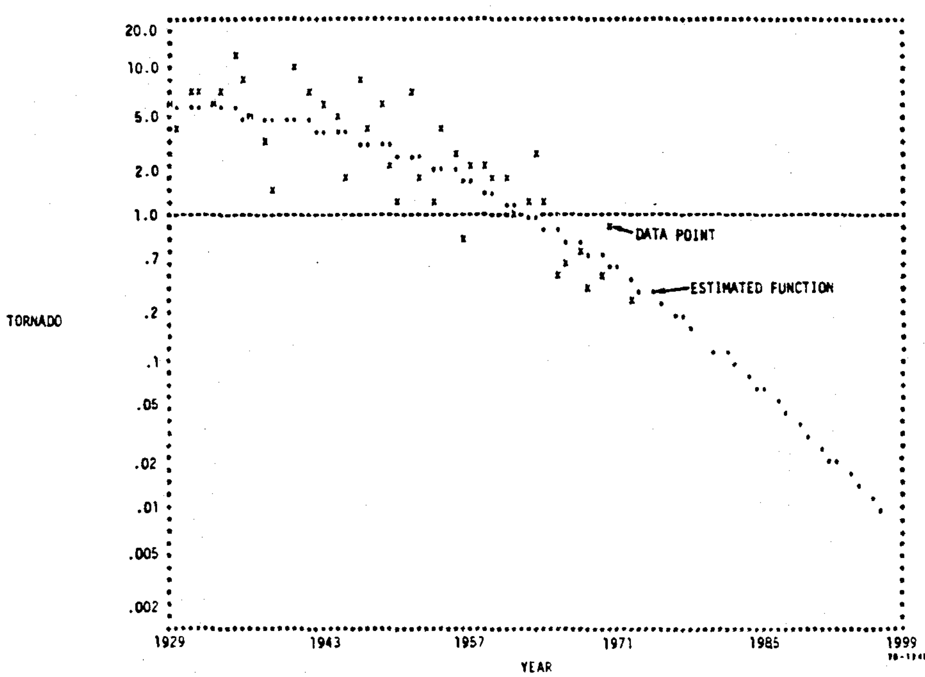


Figure 3-48. Plot of (Deaths/Million $ Damage) Due to Tornado Versus Year

calculated from the average of three tsunamis. Because a warning system was not present for those tsunamis, but is now available, the predicted deaths due to tsunami should be taken as an upper bound.

Dacy and Kunreuther [1969] suggested that deaths per million dollars damage declined over the period 1930-1964 because of warnings, stronger structures, and a higher wealth per capita. In order to examine this contention it was necessary, by estimating the wealth per capita exposed, to normalize the effect of the change in structure value to determine the impact of time-dependent technological change. Due to data limitations, this was only performed with U.S. hurricane and earthquake data from 1933 forward. For these hazards and time period, well-defined areas of impact and reliable economic estimates were available for analysis. Because no earthquake in the sample had a prior warning, while hurricanes have been predicted with increasing accuracy, a comparison of these two hazards can provide an indication of the effects of warnings versus building code requirments.

To account for the differences in structure value per capita in different locations at different periods in time, a relative value of structures per capita was computed to scale the dollar losses reported for each event. To account for the regional effect, the relative income per capita was used. The annual structure values per person were estimated for private structures, both residential and commercial. Using the estimates from the Bureau of Economic Analysis [1974], and from Young [1971], (in constant 1967 dollars), a yearly estimate of total private structure wealth was made. The estimated total population figure [U.S. Bureau of Census, 1971] for corresponding years was then used to compute a private structure value per capita, as shown in Table 3-17. These annual national estimates were then weighted by the interpolated relative per capita income in the area of primary effect for the year of the event, available by SMSA and BEA areas for years back to 1929 [Water Resources Council, 1974].

For example, in the case of the 1933 earthquake in Long Beach, California, the relative per capita income for the Long Beach - Los Angeles SMSA was estimated as 1.41 times the national average in 1933. Therefore, the value of private structures was estimated using the 1.41 factor. Figure 3-49 shows the relative structure value per capita in 1933 compared to 1970 is approximately 0.79.

	LOCATION		YEAR	DEATHS	NORMALIZED[1] IN 1967$	RELATIVE STRUCTURE[2] VALUE/CAPITA
DATA FOR HURRICANE	KEY LARGO	FLORIDA	29.0	3.00	3554.47	.438
	COLUMBIA	TEXAS	32.0	40.0	60550.4	.300
	BROWNSVIL	TEXAS	33.0	40.0	86705.9	.356
	JUPITER	FLORIDA	33.0	2.00	20829.7	.507
	CPHATTERA	NOCAROLINA	33.0	21.0	9563.15	.269
	FLA KEYS	FLORIDA	35.0	408.	27559.5	.525
	MIAMI	FLORIDA	35.0	19.0	14978.9	.686
	CPHATTERA	NOCAROLINA	36.0	2.00	13294.2	.287
	PROVIDENC	RHODE IS	38.0	600.	723662.	.994
	CHARLESTO	SOCAROLINA	40.0	34.0	56527.6	.293
	MATAGURDA	TEXAS	41.0	4.00	16955.5	.802
	MIAMI	FLORIDA	41.0	5.00	1824.66	.869
	PT LAVACA	TEXAS	42.0	8.00	133950.	.402
	TORTUGAS	FLORIDA	44.0	18.0	190529.	.593
	PT LAVACA	TEXAS	45.0	3.00	92298.1	.402
	HOMESTEAD	FLORIDA	45.0	4.00	165404.	.606
	HILLSBORO	FLORIDA	47.0	51.0	277901.	.587
	MIAMI	FLORIDA	47.0	1.00	38363.5	.773
	KEY WEST	FLORIDA	48.0	3.00	41475.3	.581
	JUPITER	FLORIDA	49.0	2.00	124301.	.581
	FREEPORT	TEXAS	49.0	2.00	23539.3	.413
	CEDAR KEY	FLORIDA	50.0	2.00	7744.94	.586
	MIAMI	FLORIDA	50.0	4.00	52571.7	.733
	LONG IS	NEW YORK	54.0	21.0	67729.7	.740
	CAPE FEAR	NOCAROLINA	54.0	98.0	829235.	.373
		NOCAROLINA	55.0	7.00	202315.	.538
	GRAND ISL	LOUISIANA	56.0	15.0	67879.6	.447
	OAK GROVE	LOUISIANA	57.0	390.	398468.	.443
	BEAUFORT	NOCAROLINA	59.0	22.0	36819.8	.432
	FLA KEYS	FLORIDA	60.0	50.0	637354.	.753
	PT LAVACA	TEXAS	61.0	46.0	822160.	.550
	MIAMI	FLORIDA	64.0	3.00	161203.	.851
	ST AUGUST	FLORIDA	64.0	5.00	458374.	.562
	FRAKLIN	LOUISIANA	64.0	38.0	232768.	.573
	FLA AND L	FLORIDA	65.0	75.0	.185013E+07	.812
	PORTRICHE	FLORIDA	66.0	6.00	18243.1	.566
	COLUMBIA	MISSISSIPP	69.0	256.	.219346E+07	.569
	RAYMONDVI	TEXAS	67.0	15.0	450784.	.443
	CORPUSCHR	TEXAS	70.0	11.0	721315.	.540
DATA FOR EARTHQUAKE	LONG BEACH	CALIFORNIA	33.0	115.	91590.7	1.12
	HELENA	MONTANA	35.0	4.00	13380.4	.722
	IMPERIALVA	CALIFORNIA	40.0	9.00	18525.9	.767
	SANTABARBA	CALIFORNIA	41.0	*.	547.776	1.03
	PUGET SOUN	WASHINGTON	49.0	8.00	50613.0	.666
	KERN CO	CALIFORNIA	52.0	14.0	105041.	.713
	EUREKA	CALIFORNIA	54.0	1.00	2973.35	.871
	FALLON	NEVADA	54.0	*.	1025.59	.842
	OAKLAND	CALIFORNIA	55.0	1.00	1184.89	1.04
	SANFRANCIS	CALIFORNIA	57.0	*.	1112.00	1.06
	HEBGEN LAK	MONTANA	59.0	28.0	16958.9	.737
		HAWAII	60.0	61.0	38590.0	.744
	WEST COAST	WEST COAST	64.0	125.	546684.	.977
	PUGET SOUN	WASHINGTON	65.0	7.00	15749.7	.839
	SANTA ROSA	CALIFORNIA	69.0	*.	7901.30	.836
	SANFERNAND	CALIFORNIA	71.0	58.0	345011.	1.14

(1) NORMALIZED TO THE 1970 STRUCTURE VALUE/CAPITA.

$$\text{NORMALIZED DAMAGES} = \frac{\text{(DAMAGES)}}{\text{(RELATIVE STRUCTURE VALUE/CAPITA)}}$$

(2) RELATIVE TO 1970 NATIONAL STRUCTURE VALUE/CAPITA.

*NO DATA AVAILABLE

SOURCES FOR HURRICANE [Sugg, et al, 1971]
FOR EARTHQUAKE [Disaster Preparedness, 1972]

Table 3-17. Hurricane and Earthquake Data Used in Time Effect Analysis

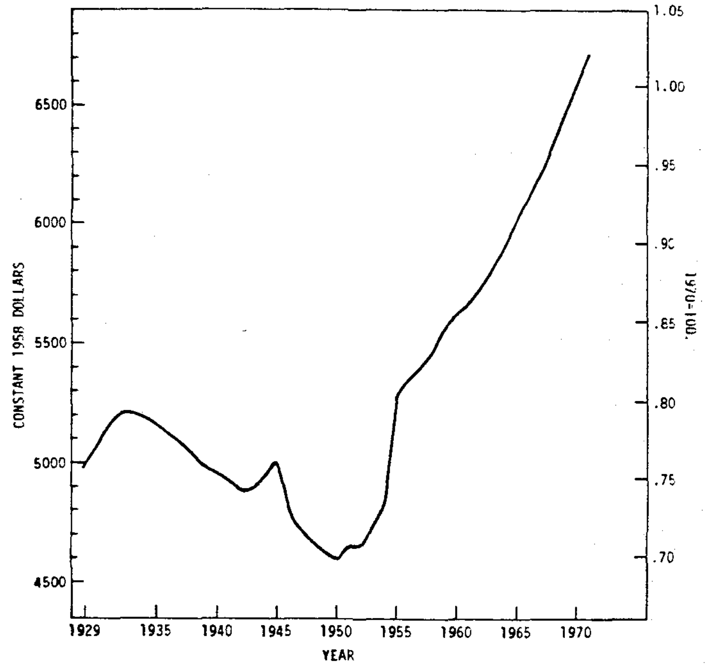


Figure 3-49. Private Structure Value Per Capita in the U.S., 1939-1971

Thus, the relative structure value per capita in Long Beach, California in 1933 compared to the 1970 national average is 1.41 x .79 or 1.12. To normalize the dollar losses reported for the 1933 Long Beach earthquake, the dollar losses in 1967 dollars of $81.8 million is multiplied by 1.12 to yield a normalized dollar value of $91.6 million (in 1967 constant dollars). Table 3-17 lists the life loss, the normalized dollar losses, and the value per capita relative to the 1970 national average.

By weighting the damages by the ratio of the historical per capita value to the 1970 per capita structure value, the effect of the regional and time dependent factors of the variations in wealth-at-risk can be factored out. Then the time effect is a better indicator of man's changing ability to cope with the occurrence of the disaster.

The relationship used by Blume [1971] for earthquake was:

$$\text{Lives Lost} = \alpha \times (\text{Damages})^{B}$$

A modification to this relationship was made to include the date of the event:

$$\text{Lives Lost} = \alpha \times (\text{Damages})^{B_1} \times (\text{year} - 1900)^{B_2}$$

Table 3-18 lists the life loss totals by hazard for 1970 and 2000 as calculated by the model described above. Expansive soil is limited to property damage. Because the model utilized in estimating riverine flooding losses is different than the approach used in the other hazards, no independent method was used to estimate riverine deaths. It was assumed that such deaths would exhibit the same relationship to dollar losses as that calculated for storm surge.

	1970	2000
EARTHQUAKE	273	400
TORNADO	392	920
HURRICANE	62	153
STORM SURGE	37	103
TSUNAMI*	20	44
SEVERE WIND	5	11
EXPANSIVE SOIL	NA**	NA**
RIVERINE FLOODING	190†	159†

*These estimates assume no warning prior to event.

**Expansive soil does not have associated life loss estimates

†Riverine flooding life loss was estimated using a completely different methodology. See Lee, et. al., 1976.

Table 3-18. Life Loss by Hazard

Housing Losses

To estimate dollar losses to housing, the value of housing per capita was used to estimate the value at risk of residential structures. In estimating the number of houses destroyed, the value at risk was changed from dollars per capita to housing units* per capita. Thus, the estimated values of housing loss reflect the number of such units lost.

*A housing unit is defined as in the Census of Housing as: "a house, an apartment, a group of rooms, or single room occupied or intended for occupancy as separate living quarters...", [U.S. Dept. of Com. 1972, App-5]

The damage calculations were made by applying the annual average percent damage* to the values of structures at risk, according to construction types, in a specific county. Thus, if the number of housing units of a particular type in a county was assumed to be 10,000 and the annual probabilities of different damage states are given as in Table 3-19, then the aggregate number of housing units destroyed is 90.2. Of those, only 10 are totally destroyed (or 100% distribution), and those in the light, moderate, and heavy damage states account for over 40% of the total.

DAMAGE STATE	RANGE OF DAMAGE RATIOS	GEOMETRIC MEANS OF DAMAGE RATIOS	HYPOTHETICAL ANNUAL PROBABILITY OF OCCURRENCE	EFFECTIVE ANNUAL DAMAGE RATIOS	HOUSING UNITS AT RISK	HOUSING UNITS DESTROYED
LIGHT	.0005 - .0125	.0025	.100	.00025	10,000	2.5
MODERATE	.0125 - .0750	.0306	.050	.00153	10,000	15.3
HEAVY	.0750 - .6500	.2208	.010	.00221	10,000	22.1
SEVERE	.6500 - 1.0000	.8062	.005	.00403	10,000	40.3
COLLAPSE	1.0000	1.0000	.001	.00100	10,000	10.0
TOTAL				.00902		90.2

Table 3-19. Example of Estimates of the Distribution of Housing Losses

Knowledge of the total number of housing units destroyed does not convey the scale of the risk of the hazard; knowledge of the number of housing units affected by damage in each damage state is more informative. By utilizing the average damage ratio for each damage state, the total number of housing units affected can be estimated. For every house totally destroyed due to light damage, many more housing units had to be damaged, according to the .0025 rate.

One Housing Unit totally destroyed = .0025 x number of housing units affected by light damage state

From this relationship it is seen that the reciprocal of the average damage rate gives the number of houses affected for each house totally destroyed, at each damage state.

*An assumption is made that the repair/replacement ratios are applicable to the determination of housing damage rates.

In the example community shown in Table 3-19, with 10,000 housing units at risk, there would be 16.56% chance that any one housing unit would be affected in any year. But of those affected, over 60% would be in the category of light damage, and less than 10% would have damage ratios above .075%. Table 3-20 extends the example in Table 3-19 to show the number of housing units affected.

DAMAGE STATE	MEAN DAMAGE RATIO	NUMBER OF HOUSING UNITS AFFECTED PER HOUSING UNITS DESTROYED	HOUSING UNITS DESTROYED	HOUSING UNITS AFFECTED	PERCENTAGES IN EACH DAMAGED STATE
LIGHT	.0025	400.0	2.5	1000.0	60.4%
MODERATE	.0306	32.6	15.3	499.0	30.2%
HEAVY	.2208	4.5	22.1	9.9	6.0%
SEVERE	.8062	1.2	40.3	48.0	2.8%
COLLAPSE	1.0000	1.0	10.0	10.0	.6%
TOTAL			90.2	1656.0	100.0%

Table 3-20. Example Computation of Number of Housing Units Affected

Homelessness

In order to quantify homelessness, a time element and an occupancy factor were used to estimate the number of persons displaced by given levels of housing loss. From Whitman et. al. [1974], estimates of the "time of inoperations," on building use time lost due to repair and restoration, were made by damage state. [See Table 3-21] These estimates can then be applied to the number of housing

DAMAGE STATE	HOUSING UNITS AFFECTED	TIME OF INOPERATION IN YEARS	PERSONS PER HOUSING UNIT	HOMELESSNESS (IN PEOPLE-YRS)
LIGHT	2.5	.00000	3.0	0.0
MODERATE	15.3	.00055	3.0	0.0
HEAVY	22.1	.02600	3.0	1.8
SEVERE	40.3	.50000	3.0	60.0
COLLAPSE	10.0	1.00000	3.0	30.0
TOTAL	90.2			92.3

Table 3-21. Example Estimation of Homelessness

units destroyed at each level. Table 3-21 gives the times of inoperation, the number of housing units destroyed, and the computed homelessness, assuming a national average of 3 persons per housing unit in the example county. In this example, the number of people displaced in one year would amount to 92.3 or about 3% of the county's population of 30,000 living in the structure type. The national average percent of "year round vacant for rent" housing units as recorded in the 1970 Census of Housing [Bureau of Census, 1972] is 2.46%; thus, the number of vacant housing units in this example community is estimated as 246, or housing for 738 persons.

The annual rates assume that every year a little of each possible disaster occurs, but in reality this is not the case. When a disaster occurs, the effects can be distributed over an area so wide that local resources may be overwhelmed, with the possible exception of tornado, storm surge, and tsunami, which may be of relatively local scale. Also, the type of housing units destroyed and those already vacant may be sufficiently dissimilar in type and rental costs that direct tenant transfer may be impossible.

Table 3-22 lists the expected number of homes destroyed, homes affected, and homelessness for hurricane, tornado, severe wind, tsunami, storm surge, earthquake, landslide, and expansive soil (data for riverine flood was not comparable). On a national scale the gradual effect of the annual probabilities for different levels is more realistic, due to the aggregation of the probabilities of many occurrences over a year.

HAZARD	# OF HUs TOTALLY DESTROYED (100% LOST)	# OF HUs AFFECTED BY SOME DAMAGE	HUs OUT OF SERVICE FOR ONE YEAR	PEOPLE DISPLACED FOR ONE YEAR (HOMELESSNESS)	HUs AT RISK X10^6	AVG. VALUE HUs AT RISK (STRUCTURE ONLY)	AVG. VALUE OF HUs AFFECTED BY SOME DAMAGE IN 1970$	AVG. VALUE LOSS OF HUs AFFECTED IN 1970$	AVG. # OF PEOPLE/ HUs IN AREAS AT RISK	% CHANCE OF BEING AFFECTED IF IN EXPOSED AREA	% OF CHANCE OF BEING HIT ON NATIONAL SCALE
HURRICANE	28,190.	984,684.	10,388.0	34,508.0	20.76	17,400.0	16,000.0	980.0	3.34	2.210%	0.680%
SEVERE WIND	485.	16,314.	255.6	767.4	67.56	16,372.0	15,670.0	463.0	3.00	.024%	0.024%
TORNADO	30,970.	45,486.	25,044.6	88,144.0	60.01	16.081.1	16,215.0	11,548.5	3.52	.072%	0.064%
TSUNAMI	233.	1,369.	100.0	345.0	6.34	17,296.8	19,407.7	3,303.1	3.45	.022%	.002%
EARTHQUAKE	20,510.	2,805,925.	254.7	735.9	47.79	16,632.3	17,269.6	126.0	2.89	5.870%	4.150%
STORM SURGE	24,672.	515,595.	2,532.1	7,208.5	12.89	17,879.7	13,486.0	645.0	2.85	4.000%	0.760%
LANDSLIDE	--*		--*	--*	67.39	16,316.8	16,316.8	1.7	3.00	---*	---*
EXPANSIVE SOIL	--*		--*	--*	67.39	16,316.8	16,316.8	8.9	3.00	---*	---*

*Expansive soil and landslide did not have a damage state breakdown, thus only the averages are available for reporting

Table 3-22. Housing Losses by Hazard

The values of losses and of housing units at risk are taken from the structure value calculations discussed in Hirschberg et. al. [1978]. The average number of persons per housing unit varies by hazard, and is based on the census of housing data. It should be noted that the structure value is per person, based on the 1970 stock of buildings, in 1970 dollars.

Unemployment

Using the income losses calculated in Hirschberg, et. al. [1978], the number of person-years of unemployment can be calculated from the ratio of payroll-to-employees for each economic sector. From the data in the Multi-Regional Input-Output Model for the United States, [Polenske, 1970] estimates are available of the number of employees by sector and the payrolls by sector [Rogers, 1972]. Table 3-23 lists these ratios.

ECONOMIC SECTORS	AVERAGE INCOME
HOUSEHOLD	1,681.5
MINING, FARMING	3,063.2
CONSTRUCTION	6,716.5
MANUFACTURING	6,712.6
TRANSPORTATION & UTILITIES	7,520.9
WHOLESALE AND RETAIL TRADE	4,646.0
FINANCE, INSURANCE, ETC.	5,887.1
SERVICES	4,464.8
FEDERAL GOVERNMENT	6,463.8
STATE AND LOCAL GOVERNMENT	5,860.5

Table 3-23. Average Income Per Employee in 1970$ in 1963

The income per employee ratios are available by state and were used to weight the income losses to derive the total unemployment by sector. The unemployment computed here is not the statistic often cited as a percentage of the work force, but is an unemployment statistic with a time dimension. For example, a loss in income to a basic sector (farming and mining) is given as $3.0 million for a year due to a particular hazard's annual risk. From Table 3-23 we calculate an average income of $3,063 per employee annually. Thus, the loss of $3,000,000 of income could result in approximately 980 person-years of unemployment, in the form of either 980 persons unemployed for a year or 11,760 persons unemployed for a month.

Table 3-24 lists the unemployment estimated for each sector due to hurricane wind, severe wind, tornado, storm surge, tsunami and earthquake. Again, due to limitations in the expansive soil and landslide models, unemployment estimates were not calculated. The unemployment distribution follows that of income loss. Thus, all employees in the farming and mining sector are exposed to severe wind hazards, yielding 19.1 person-years lost in 1970. About five percent of the total employed suffered some joblessness in this sector from severe winds. Again, the usual cautions pertaining to this study's county level data should be observed.

The percentage of the total loss listed by sector for each hazard demonstrates the regional variation of the hazards and the types of exposure.

The exposure given in terms of employee-years is higher than two estimates of the total employment for 1970. The number used as shown in Table 3-24 is 11.0% greater than as reported in the OBERs report [U.S. Water Resources Council, 1972]. These discrepancies arise to some extent because of the date of the input-output data, 1963; thus, the ratios of output per capita as given in Table 3-23 may tend to be low.

The estimates of life loss, which are from crude data and incomplete information affecting a persons' survival of an event, should be used with caution. The vulnerability of housing and the reliance on the "time of inoperation" method determine the viability of the estimates for homelessness and homes lost. And the same caveats expressed for the reliability of the income loss data can be repeated for the estimates of unemployment.

	HOUSEHOLD	FARMING & MINING	CONSTRUCTION	MANUFACTURING	TRANSPORTATION & UTILITIES	RETAIL & WHOLESALE TRADE	FINANCE & INSURANCE	SERVICES	FEDERAL GOVERNMENT	STATE & LOCAL GOVERNMENT	TOTAL
Estimated Employee Years	1,456.0	7,283.0	4,548.0	20,630.0	4,711.0	17,685.0	4,332.0	16,845.0	3,265.0	8,888.0	89,643.0**
Percent Distribution of Total	1.6	8.1	5.1	23.1	5.3	19.7	4.8	18.8	3.6	9.9	100.0
SEVERE WIND											
Percent of Exposure	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Person Years	37.9	19.1	5.6	28.1	8.4	95.0	77.0	77.7	9.5	14.6	372.9
Percent Distribution of Total	10.2	5.1	1.5	7.5	2.3	25.5	20.6	20.8	2.5	3.9	100.0
HURRICANE											
Percent of Exposure	32.9	21.5	34.4	30.5	34.0	32.6	39.2	35.7	36.3	32.7	32.9
Person Years	1,841.0	1,411.0	583.0	2,408.0	810.0	4,254.0	3,997.0	3,818.0	653.0	1,228.0	21,003.0
Percent Distribution of Total	8.8	6.7	2.8	11.5	3.9	20.2	19.0	18.2	3.1	5.8	100.0
TORNADO											
Percent of Exposure	92.7	94.0	90.6	91.6	85.2	88.4	82.6	87.4	87.8	87.5	88.5
Person Years	2,058	4,289.0	1,507.0	8,626.0	2,147.0	12,980.0	10,190.0	10,290.0	1,977.0	3,476.0	57,540.0
Percent Distribution of Total	3.6	7.5	2.6	15.0	3.7	22.6	17.7	17.9	3.4	6.0	100.0
TSUNAMI											
Percent of Exposure	8.0	3.3	7.6	7.2	10.7	9.4	10.8	9.4	11.3	8.4	8.6
Person Years	7.2	.3	.8	1.5	23.7	21.4	15.4	22.9	2.8	1.6	97.6
Percent Distribution of Total	7.4	.3	.8	1.5	24.3	21.9	15.8	23.5	2.9	1.6	100.0
EARTHQUAKE											
Percent of Exposure	80.7	71.9	70.1	67.8	72.3	70.8	74.2	73.0	76.0	71.2	71.4
Person Years	21.4	61.3	12.5	55.8	24.5	61.4	59.0	47.5	35.1	35.4	413.9
Percent Distribution of Total	5.2	14.9	3.0	13.5	5.9	14.8	14.3	11.5	8.5	8.6	100.0
STORM SURGE											
Percent of Exposure	20.8	14.2	21.2	17.7	24.3	21.0	27.7	23.2	18.1	19.9	20.9
Person Years	47.7	48.4	8.4	28.0	15.2	77.5	57.0	59.4	9.6	17.5	368.7
Percent Distribution of Total	12.9	13.1	2.3	7.6	4.1	71.1	19.5	16.1	2.6	4.7	100.0

*The percent of the total number employed who would lose their jobs.

**This estimate is 11.9% greater than the total employment estimated for 1970 in the OBERs report [1974] and 12.2% greater than the employment reported in the Statistical Abstract for 1970 [U.S. Bureau of the Census, 1972]

Table 3-24. Distribution of Annual Unemployment by Economic Sector and Hazard in Person Years Unemployed for 1970

This chapter has presented some further calculations that can be made from the basic building loss model, which can lend insight into facets of the natural hazard phenomena other than direct economic losses. These losses are defined for the purposes of this study as social impacts, although they are not intended to represent the entire range of non-economic effects of extreme natural events.

Chapter Four

NATURAL HAZARDS LOSS ANALYSIS

Introduction and Summary

Utilizing the methods described in the preceding chapter, the loss analysis component of this study focused on several objectives: (1) identification of the primary, secondary, and higher-order effects associated with the exposure of people and buildings to nine natural hazards; (2) determination of the site and characteristics of the U.S. human and building populations which were exposed to various intensity levels of each of these hazards in 1970 and which are expected to be exposed to the same phenomena in the year 2000; (3) quantification of the magnitude and geographic occurrence of seven major effects associated with the exposure of buildings, building contents, and building occupants to these same hazardous natural events. In most cases, data on hazard effects were probabilistically derived, were calculated as annualized or "annual expected" estimates, and - except for riverine flooding - were generated or are retrievable at the scale of individual counties, states, and the nation as a whole.

The loss analysis also included the development of an annual expected hazard-specific and aggregated building damage rate for each state and county in the United States, and a hazard-specific rate for other selected hazard zones or areas. The building damage rate for any area is the annual expected dollar value of hazard-induced damage to buildings divided by the total value of all buildings within the area and is a crude indicator of the level of hazard related risk associated with a particular place. The rate is a function of two sets of factors: (1) the probability of hazard occurrence within the area, by various intensity levels, and; (2) the level of vulnerability of area buildings and property to hazard-induced damage.

For any given area, the annual expected dollar losses which were derived from the loss analysis are expressed as the sum of the natural hazard dollar losses (in 1970 dollars) which are expected to be incurred within the area over a period of years divided by the number of years in the period. Accordingly, this calculation treats all of the losses which are expected to occur over a large frame of years as though the losses were sustained in equal amounts during each of the several years of exposure. Thus, the dollar consequences of such infrequent events as major earthquakes are reported as the sum of such losses over a large time frame divided by the number of years in that time frame, including the years in which no such event occurred or was expected to occur. Dollar losses inventoried in the study include those resulting from damage to buildings, damage to building contents, supplier losses due to increased transportation costs, and income reduction sustained as a result of the closure or slow-down of economic activities conducted in damaged buildings.

Completion of the loss analysis revealed that annual expected losses from exposures to nine natural hazards totaled $8094 million in 1970 [See Table 4-1] and that under current conditions, these losses will increase to $17,779.4 million in the year 2000 [See Table 4-2]. In the latter year, annual expected dollar losses will total as follows for each hazard: (1) riverine flooding, $3175.3 million; (2) tornado, $5219.1 million; (3) hurricane, $3526.3 million; (4) expansive soils, $997.1 million; (5) storm surge $2342.9 million; (6) earthquake, $1553.7 million; (7) landslide, $871.2 million; (8) severe wind, $53.4 million; (9) tsunami, $40.4 million. In the year 2000, annual expected losses from natural hazards will exceed the sum of the actual 1970 expenditures for losses chargeable to all state and local police department operations, all crimes against properties, all annual investments in water pollution control facilities, all business losses due to six major types of criminal activity, and all building losses due to fires. In addition, natural hazard exposures in the year 2000 are expected to result in 1790 deaths, 172,084 housing units destroyed, 168,302 person-years of homelessness, and 207,492.2 person-years of unemployment.

Natural Hazard Effects

Whenever persons or property are exposed to hazardous natural events, the exposure may result in chains of effects or consequences, some of which may be disvalued by subsets of the human population. Among such consequences, or impacts, are those depicted in Figure 4-1.

The primary effects of a natural hazard are those instantly and directly resulting from the occurrence of the hazard and the exposure of people or property to that hazard. Secondary effects are those which are the instant and direct outcome of

HAZARD	EXPECTED ANNUAL LOSSES								
	DOLLAR LOSSES RESULTING FROM INDICATED FACTOR (MILLIONS OF DOLLARS)					OTHER LOSSES			
	(1) BUILDING DAMAGE	(2) CONTENTS DAMAGE	(3) INCOME LOSS[(a)]	(4) SUPPLIER LOSS[(b)]	(5) TOTAL (1-4)	(6) NUMBER OF DEATHS	(7) HOUSING UNITS LOST	(8) PERSON YEARS OF HOMELESSNESS	(9) PERSON YEARS OF UNEMPLOY.
1. EARTHQUAKE	655.2	123.23	2.651	0.030	781.1	273	20,485	736	413.5
2. EXPANSIVE SOIL	798.1	-	-	-	798.1	-	-	-	-
3. HURRICANE	685.5	267.57	101.803	1.092	1056.0	62	31.885	34,505	21,003.7
4. LANDSLIDES	370.3	-	-	-	370.3	-	-	-	-
5. RIVERINE FLOODING	1901.0	847.02	10.166	0.120	2758.3	190	-	-	-
6. SEVERE WIND	11.4	4.47	2.090	0.022	18.0	5	547	852	373.1
7. STORM SURGE	441.6	197.24	2.367	0.028	641.2	37	24,521	7,290	369.7
8. TORNADO	879.8	469.93	302.821	3.451	1656.0	392	36,212	86,122	57,541.6
9. TSUNAMI	8.7	5.54	0.727	0.012	15.0	20	234	345	97.5
TOTALS	5751.6	1915.0	422.625	4.755	8094.0	979	113,884	129,850	79,799.1

(a) Total loss of worker earnings associated with hazard caused unemployment

(b) Total loss of income experienced by suppliers of businesses and industries experiencing hazard-induced shutdowns

Table 4-1. Expected Annual Losses from Natural Hazard Exposures in the United States by Type of Hazard and Type of Loss, 1970

HAZARD	EXPECTED ANNUAL LOSSES								
	DOLLAR LOSSES RESULTING FROM INDICATED FACTOR (MILLIONS OF DOLLARS)					OTHER LOSSES			
	(1) BUILDING DAMAGE	(2) CONTENTS DAMAGE	(3) INCOME LOSS[(a)]	(4) SUPPLIER LOSS[(b)]	(5) TOTAL (1-4)	(6) NUMBER OF DEATHS	(7) HOUSING UNITS LOST	(8) PERSON YEARS OF HOMELESSNESS	(9) PERSON YEARS OF UNEMPLOY.
1. EARTHQUAKE	1177.0	372.78	3.906	0.048	1553.7	400	22,868	648	634.9
2. EXPANSIVE SOIL	997.1	-	-	-	997.1	-	-	-	-
3. HURRICANE	1742.0	1504.98	276.191	3.095	3526.3	153	52,237	48,271	58,223.7
4. LANDSLIDE	871.2	-	-	-	871.2	-	-	-	-
5. RIVERINE FLOODING	1594.0	1572.54	8.68	.105	3175.33	159	-	-	-
6. SEVERE WIND	24.8	23.8	4.696	0.051	53.4	11	748	1,014	850.9
7. STORM SURGE	1176.0	1160.43	6.407	0.077	2342.9	103	43,757	10,330	1,018.3
8. TORNADO	2058.0	2401.32	750.780	9.042	5219.1	920	52,119	107,650	146,568.5
9. TSUNAMI	19.8	19.10	1.479	0.027	40.4	44	335	389	195.9
TOTALS	9659.9	7054.95	1052.139	12.445	17,779.43	1790	172,084	168,302	207,492.2

(a) Total loss of worker earnings associated with hazard caused disruption

(b) Total loss of income experienced by suppliers of business and industries experiencing hazard-induced shutdowns

Table 4-2. Expected Annual Losses from Natural Hazard Exposures in the United States, by Type of Hazard and Type of Loss, 2000 primary effects or consequences. Similarly, secondary effects are proximate causes of still other consequences which are referred to as higher-order effects. The hazard-induced effects or consequences which were quantified through performance of the loss analysis included: (1) economic losses to buildings (building losses), (2) economic losses to the contents of buildings (contents losses),

PRIMARY EFFECTS	SECONDARY EFFECTS	HIGHER ORDER EFFECTS
1. INJURY OR DEATH TO HUMAN BEINGS	1. HOMELESSNESS	1. UNEMPLOYMENT
2. INJURY OR DEATH TO LIVESTOCK & DOMESTIC ANIMALS	2. SHUTDOWNS OR SLOWDOWNS IN BUSINESS AND INDUSTRY	2. LOSS OF PERSONAL FAMILY INCOME
3. DAMAGE TO STRUCTURES AND THEIR CONTENTS	3. DISRUPTION OF UTILITY SERVICE	3. LOSS OF BUSINESS-INDUSTRIAL INCOME
4. DAMAGE TO COMMUNITY FACILITIES AND INFRASTRUCTURE	4. FINANCIAL EXPENDITURES BY COMMUNITIES, FAMILIES, & BUSINESSES FOR CLEAN-UP & RECOVERY OPERATIONS	4. DIVERSION OF INVESTMENT CAPITAL TO REHABILITATION & RECOVERY PROJECTS
5. DAMAGE TO AUTOMOBILES, BOATS, & OTHER PERSONAL PROPERTY	5. FINANCIAL EXPENDITURES BY COMMUNITIES, FAMILIES, & BUSINESSES FOR REPAIR OR REPLACEMENT OF DAMAGED STRUCTURES, BUILDING CONTENTS, & OTHER PROPERTY	5. ALTERATION OF LAND AND PROPERTY VALUES
6. DAMAGE TO CROPS, FORESTS, AND ORNAMENTAL VEGETATION	6. FINANCIAL EXPENDITURES BY GOVERNMENT FOR REPAIR AND/OR REPLACEMENT OF DAMAGED COMMUNITY FACILITIES & INFRASTRUCTURE	6. ALTERATION OF AREA POPULATION GROWTH TRENDS
7. ALTERATION OF VALUED GEOPHYSICAL CONFIGURATIONS	7. INSURANCE PAYOUTS TO POLICY-HOLDERS	7. ALTERATION OF POPULATION MIGRATION PATTERNS
8. PSYCHOLOGICAL TRAUMA		8. ALTERATION OF COMMUNITY OVERHEAD BURDENS
9. LOSS OF COMMUNITY HOUSING STOCK		9. INCREASED TAX BURDENS TO FINANCE RECOVERY OPERATIONS
		10. ALTERATION IN COMMUNITY SOCIO-ECONOMIC VIABILITY
		11. ALTERATIONS IN FAMILIAL SOCIO-ECONOMIC VIABILITY
		12. DEPLETION OF PERSONAL OR BUSINESS SAVINGS OR CAPITAL
		13. FINANCIAL COSTS TO SUPPLIERS

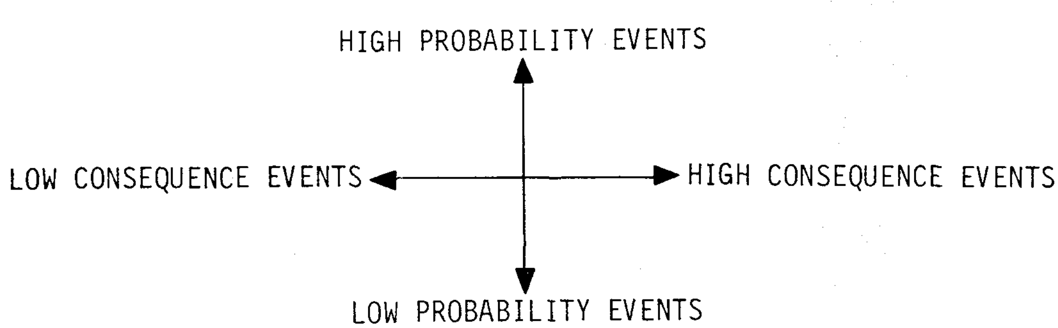
Figure 4-1. Taxonomy of Natural Hazard Effects

(3) economic losses in the impacted area due to increased transportation costs of goods (supplier losses), (4) economic losses in the form of lost take-home pay (income loss), (5) years of unemployment induced by hazard-caused damage to buildings and their contents (unemployment), (6) years of homelessness induced by damage to private residences (homelessness), and (7) loss of life resulting from the occurrence of hazardous natural events (life loss).

Of course, several other major effects also are associated with the exposure of people, buildings, and other properties to hazardous natural events. Although not inventoried in this study, some of the most significant of these include: (1) damage to community infra-structure, including utility lines, pipelines, railroads, streets, highways, and other similar facilities, (2) damage to personal property not countable as building contents, such as automobiles, boats, and recreational equipment, and (3) damage to growing crops, livestock, and ornamental vegetation. From an economic point of view, the annual expected dollar losses associated with these types of hazard effects may well be equal to or greater in magnitude than those inventoried in this study.

Being guided by a primary focus on hazard-induced damage to buildings, the study revealed considerable differences in the type, magnitude, and frequency of damage to buildings as a function of the type of hazard to which the buildings are exposed. Taking into account the specific geographic areas in which each type of hazard occurs and the vulnerability of buildings to the hazard, the computer models used in the study disclosed that light-to-moderate damage would be sustained by 61.6% of the buildings experiencing damage from earthquakes, by 26.7% of those damaged by storm surge, by 18.3% of those damaged by tsunami, and by about 16% of those damaged by either hurricane winds or severe winds. Structural collapse or severe damage is expected to be experienced by 92.7% of those buildings damaged by tornadoes, by 50.7% of those damaged by hurricane winds, and by 36.1% of those damaged by tsunami (See Figure 4-2, 4-3).

Similarly, the expected frequency of building damage occurrences of various magnitudes ranges over a broad continuum as a function of the type of hazard to which buildings are exposed. For example, expansive soils may be viewed as producing frequent or near-continuous damage of light magnitude to exposed buildings; while major earthquakes, tsunamis, hurricanes, and floods may be classed as low probability but high consequence occurrences in the areas in which such events are most likely to occur. Generally, therefore, risk producing events may be ordered into four classes corresponding to the simple model presented below:



DAMAGE STATE	STRUCTURE CONDITION
None (0 - 0.5%)	No damage
Light (0.5 - 1.25%)	Minor ceiling tile or partition cracking; possible damage due to missiles.
Moderate (1.25 - 7.5%)	Many partitions cracked or ceiling tiles fallen down; a few structural members appear to be stressed beyond yield level.
Heavy (7.5 - 65%)	Significant number of structural members with structural damage, or damage to a structural system, roof having major damage.
Very Severe (65 - 100%)	Major damage; structure standing but will probably be taken down.
Collapse (100%)	Structure does not remain standing.

Figure 4-2. Damage State Description

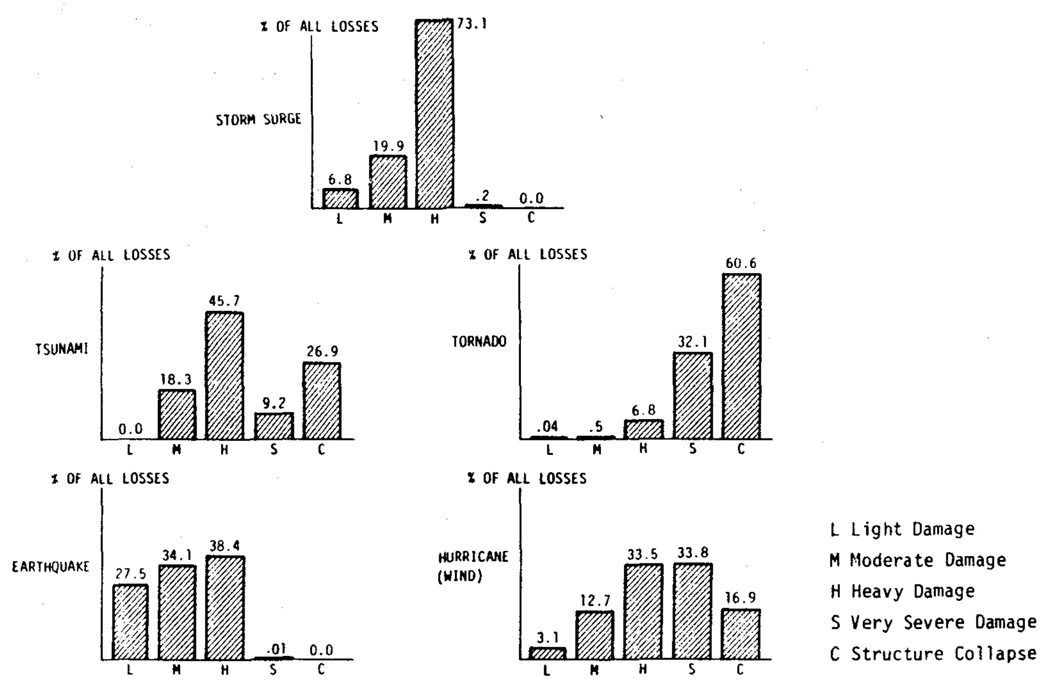


Figure 4-3. Average Proportionate Distribution of Building Damage by Selected Hazard Type in the United States and by Level of Severity of Hazard Effects

At the scale of whole communities, states, regions, and the nation as a whole, low probability but high consequence hazard events may produce catastrophic or near-catastrophic losses in the single year or month of their occurrence, and - at the time of their occurrence - may be more highly disvalued than high probability but low consequence events which may produce larger cumulative losses over any given time period.

If the real community and familial impacts of a loss are those related to the loss experiencer's perceptions of economic and other burdens at the time of loss, then the probabilistically-derived annualized estimates of natural hazard losses which were used in the loss analysis may be misleading. They may be misleading since they tend to obscure the loss experiencer's real burden and perceptions of consequences at the time a severe, but infrequently-occurring, hazardous event takes place.

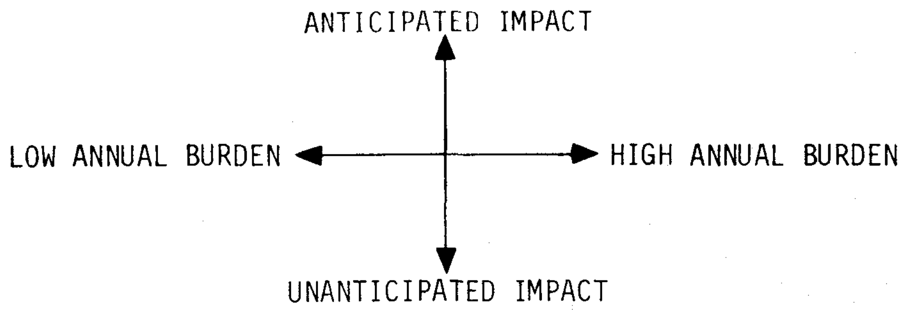
Several of the hazards which were examined in this study qualify as potentially-severe but infrequently-occurring events. Interestingly, these potentially catastrophic hazards account for the major fraction of the projected annual per capita losses for both 1970 and 2000. Thus, projected annual per capita losses for earthquakes, hurricanes, riverine flooding, storm surge, tornadoes, and tsunamis total $33.95 for 1970, or 85.39% of all projected natural hazard per capita losses for that year. For the year 2000, projected per capita annual losses for the same "catastrophic" hazard events totals $61.93 or approximately 89.22% of the projected per capita hazard losses for that year. If only one-half of the annual expected per capita hazard losses for a community were due to infrequently occurring but high damage producing events per capita losses in the single year of the event could well press community recovery capacities and create substantial social costs as a result of the socio-economic dislocations and lengthy recovery times associated with community rehabilitation responses.

For example, if an earthquake of Richter magnitude 8.3 at its epicenter were to occur in the 39 county San Francisco area in the year 2000, it could be expected to produce damage intensities reaching 9.5 on the Modified Mercalli Intensity scale within the area, to produce building value losses at $18.2 billion, and a total loss of $39.9 billion [See Chapter 6]. Such a loss is 124% greater than the national, annual, all-hazard expected losses for the same year [See Table 4-2]. The latter, of course, represents a value derived from averaging into each year's expected losses, the cumulative, long-term losses expected to result from low-probability, high-consequence events. In one recent 10-year period, thirteen discrete events of this type produced approximately $6.4 billion in losses, and a 10-year average annual loss which was equal to 7.9% of the total, all-hazard, annual expected loss reported in this study for the year 1970 [See Tables 4-1,4-3].

MONTH/ YEAR	DISASTER	ESTIMATED DAMAGE ($M)	LIVES LOST
9/61	HURRICANE CARLA	408.3	46
3/64	ALASKA EARTHQUAKE	500.0	131
10/64	HURRICANE HILDA	100.0	38
12/64	CALIFORNIA, OREGON FLOODS	415.8	40
3-5/65	FLOODS - BASINS OF THE UPPER MISSISSIPPI, THE MISSOURI, AND THE RED RIVER OF THE NORTH	181.3	16
4/65	PALM SUNDAY TORNADO-MIDWEST	300.0	271
6/65	SOUTH PLATTE BASIN FLOODS	415.1	16
9/65	HURRICANE BETSY	1,440.0	75
9/67	HURRICANE BEULAH	200.0	15
1-2/69	CALIFORNIA FLOODS	399.2	60
8/69	HURRICANE CAMILLE	1,420.8	256
5/70	LUBBOCK, TEXAS TORNADO	135.0	26
8/70	HURRICANE CELIA	453.8	11
	TEN-YEAR TOTAL	6,369.3	1,001

Table 4-3. Significant Natural Disasters, 1961-1970 (at least 100 million in damage and 10 lives lost) [Office of Emergency Preparedness, 1972]

Without regard to its class, any effect of a natural hazard may be either <u>intrinsically</u> or <u>instrumentally</u> disvalued by individuals. When an effect is intrinsically disvalued, the effect is viewed as a problem in and of itself without regard to any subsequent effect it may induce. When an effect is instrumentally disvalued, it is viewed as a problem not because of the effect, itself, but because of the subsequent consequences or chains of consequences which it induced. A later chapter in this report utilizes the loss analysis and mitigation cost analysis results to identify candidate public problems of both an instrumental and intrinsic nature.



Consistent with the model, it seems likely that the most troublesome impacts - at time of occurrence - are those which are unanticipated and which involve a comparatively high drain on annual income and/or the loss of a large fraction of one's capital accumulation. The least troublesome probably are those which are anticipated and which involve either comparatively low annual demands on income or only a trivial proportion of one's capital assets, such as the annual costs of fire insurance and of tax burdens for fire protection abatement services. Annual costs of this sort probably are more willingly borne by the general public and are viewed as less burdensome by that public than are the comparatively large costs associated with unanticipated, low probability-high consequence hazard events. However, if these events are of such low probability that the public does not choose to engage in appropriate risk-mitigating decisions and/or actions, then a social anomaly is presented. If the general public is not highly motivated to cope with the threats posed by low probability-high consequence occurrences, nonetheless, when such phenomenon do occur, they probably are perceived as being far more burdensome and distressing than other types of events. In short, human behavior and human reaction to such events may be inconsistent with the logic and the calculus of the actuarial sciences.

Hazard Exposures and Exposure Areas

For the purposes of this report, the populations at risk of experiencing the adverse effects of natural hazard exposures are viewed as consisting of three broad classes:

1. <u>Locational risk takers</u>: The populations of people and property in this class are those located in direct contact with or in immediate proximity to specific natural hazards. For example, persons who construct structures within a 50-year flood plain, or who construct structures on steep hillsides, or who construct structures immediately adjacent to earthquake

faults would be considered locational risk takers. Such risk takers may, in turn, be considered as consisting of four groups: (a) those who take no special measures to protect themselves from their risk-taking, and; (b) those who take one or more special steps to protect themselves from risk taking, such as application of structural strengthening technologies to their buildings, purchase of insurance, or other similar measures. Each of these groups may, in turn, be viewed as consisting of "voluntary" or "involuntary" risk takers. The size of locational risk-taking groups usually can be determined only by the performance of a fine-grained analysis of a specific local land area. In this study, the size of locational risk-taking groups could not easily be determined for all hazards because of the national scope of the study and the high cost involved in identifying such groups. Nonetheless, per capita and other estimates of the losses incurred by locational risk takers are presented for a few hazards.

2. Area risk takers: This class includes those persons and properties which are located in small geographically-or politically-identifiable local areas within which segments of the land area available for development are known to exhibit particularly high hazard potentials. Thus, a person constructing a dwelling unit in the cities of Dallas or Houston, Texas could appropriately be designated as an area risk taker because of the high proportion of the land areas of these two places which are known to exhibit a high potential for expansive soil-induced damage to foundations and structures. Similarly, a person establishing residence in the San Fernando Valley of Los Angeles County or in the City of San Francisco could be declared to be an area risk taker because of the earthquake hazards known to exist in these places.

3. Communities of interest: This class of persons and property include the individuals, groups, and building wealth compromising the "environmental surrounds" of locational and area risk takers, the populations of communities which bear primary power for controlling hazard exposures or for mitigating the risks induced by such exposures, and further includes the groups within which the costs of natural hazard exposures incurred by locational and area risk takers may be distributed. Communities of interest may be viewed as consisting of several groups,

the highest and largest of which would constitute the entire population of the United States.

In most cases this study was able to identify populations at risk only at the scale of area risk takers and at the scale of communities-at-interest. Generally, references to county-level population segments should be viewed as defining area populations at risk while references to state or national-level populations should be viewed as constituting references to communities-at-interest. Thus, the finest-grained hazard exposure areas, defined in the study for selected hazards are those listed in Figure 4-4. Data for all hazards except riverine flooding also were aggregated by county and state.

ANALYSIS AREA	HAZARDS TO WHICH APPLIED
COUNTY-LEVEL AGGREGATIONS OF PEOPLE AND PROPERTY	TORNADO, HURRICANE WINDS, SEVERE WINDS, EARTHQUAKE
PROPORTIONS OF COUNTIES	EXPANSIVE SOILS, LANDSLIDE
INUNDATION AREAS (100-YEAR AND 500-YEAR)	TSUNAMI
STORM-SURGE ZONES, BY COUNTY SEGMENTS (0-20', MEAN SEA LEVEL, ADJUSTED)	STORM SURGE
RIVERINE FLOOD PLAIN ZONES, BY MULTI STATE REGIONS: 50-100 YR. (E) 25-50 YR. (D) 10-25 YR. (C) 5-10 YR. (B) 2-5 YR. (A)	RIVERINE FLOODS

Figure 4-4. Hazard Exposure Areas Utilized in Study

Populations at Risk

Expressed as a percentage of the total U.S. population, the combined populations of natural hazard exposure areas ranged downward from 100% for severe winds to only 0.05% for 100-year tsunami inundation areas [See Table 4-4]. With the exception of severe wind, earthquake, expansive soils, and hurricane wind, comparatively small fractions of the U.S. population reside in the hazard exposure areas which produce the major fraction of the nation's annual expected hazard losses.

HAZARD	TYPE OF AREA	HUMAN POPULATION EXPOSED		VALUE OF BUILDING EXPOSED TO HAZARD	
		N	PERCENT OF U. S. TOTAL	N ($ x 10^6)	PERCENT OF U. S. TOTAL
1. SEVERE WIND	COUNTIES	203,260,531	100.0	2,064,507.5	100.0
2. TORNADO	COUNTIES	181,198,749	89.1	1,788,989	89.1
3. EXPANSIVE SOILS HIGH ZONES MEDIUM ZONES LOW ZONES	FRACTIONS OF COUNTIES	 17,730,021* 23,710,910 98,320,710	 8.7** 11.7 48.4	NOT AVAILABLE	
4. EARTHQUAKE ANY INTENSITY	COUNTIES	143,169,495	70.4	1,494,293	72.4
5. EARTHQUAKE ZONE #1 ZONE #2 ZONE #3	FRACTIONS OF STATES	 120,600,000 33,340,000 38,020,000	 59.3 16.4 18.7	 1,205,138 340,210 427,860	 58.4 16.5 20.7
6. HURRICANE WIND	COUNTIES	62,741,264	30.9	682,476	30.9
7. LANDSLIDE HIGH MODERATE	COUNTIES	 44,068,071 39,426,341	 21.7 19.4	NOT AVAILABLE	
8. STORM SURGE	COUNTIES	38,387,247	18.9	438,733	21.3
9. STORM SURGE	COUNTIES SEGMENTS 0-20 FT. MEAN SEA LEVEL (ADJUSTED)	9,940,101	4.89	104,670.25	5.1
10. RIVERINE FLOOD	5,539 FLOOD PRONE CITIES: ALL ZONES 100 YR. FLOOD PL. 50 YR. FLOOD PL. 25 YR. FLOOD PL.	 24,112,000 12,056,000 8,776,416 5,830,968	 11.86 5.93 4.32 2.87	 731,977.34 364,650.79 265,471.01 175,478.42	 35.5 17.7 12.9 8.5
11. TSUNAMI	100 YR. INUNDATION AREA 500 YR. INUNDATION AREA COUNTIES CONTAINING ABOVE AREAS	109,400 237,500 18,200,851	0.054 0.117 8.95	 217,327.63	 10.5

* Number of People in Single Family Residences

** % of Total Population

Table 4-4. Exposure of Building Values and Persons to Natural Hazards in the U.S., by Type of Hazard for 1970

Thus, if one assumes that the populations of the several hazard-specific types of exposure areas are discrete, non-overlapping groups, then not more than 7.9% of the U.S. population in 1970 resided in exposure areas which produced in excess of 32.8% of the total national building damage losses arising from natural hazard exposures [See Table 4-5].

EXPOSURE AREA	POPULATION	% OF NATIONAL	LOSS (MILLIONS)	% OF NATIONAL BLDG.DAM.LOSS
RIVERINE FLOOD ZONES A - C	5,830,968	2.87	1438.8	25.02
STORM SURGE INUNDATION AREAS (0-20' MSL, ADJUSTED)	9,940,101	4.89	442.0	7.68
TSUNAMI 500-YEAR INUNDATION AREAS	237,500	.12	8.7	.15
TOTALS	16,008,569	7.88	1889.5	32.8%

Table 4-5. Hazard Exposure Areas, Population at Risk and Expected Annual Dollar Losses.

Even in the case of tornadoes, to which 89.1% of the U.S. population is exposed at some level of risk, the major burden of the risk-taking is borne by minor fractions of the exposed population. For example, in the contiguous U.S., fourteen states and the District of Columbia experience fewer than one tornado per year per 10,000 square miles of land area. In the remaining thirty-four states, strike occurrences per 10,000 square miles of land area per year are as follows: [Hart, 1976, Fig. 1-2]

STRIKE OCCURRENCES PER YEAR PER 10,000 SQUARE MILES	NUMBER OF STATES IN CLASS
1 - 1.99	10
2 - 3.99	16
4 - 4.99	4
5+	4

This phenomenon also is depicted in Table 4-6, which indicates that about 63% of all tornado strikes per year in the U.S. are experienced by less than 20% of the U.S. land area which represents a slightly lower fraction of the U.S. population.

The extent to which various proportions of the U.S. population are exposed to differing levels of risk arising from exposure to natural hazards may be suggested through use of the study-revealed building damage rates, which were associated with various areas in 1970.

In terms of the entirety of the U.S. land area, 1970 building damage losses were equal to .279% of the nation's building wealth [See Table 4-7]. At the level of whole states, only two states (Vermont and Arizona) and the District of Columbia were found to experience 1970 expected annual building damage rates which were below the rate for the nation as a whole for each of the nine hazards examined in the study [See Table 4-7]. All of the other states in the Union experienced the national building damage rate, or higher, for one or more of these same hazards.

NUMBER OF STRIKES PER GRID (1°X1°)	NUMBER OF GRIDS IN GROUP			NUMBER OF STRIKES		
	N	CUM	%, CUM	N	CUM	%, CUM
75+	11	11	1.22	917	917	7.66
50 - 74	31	42	4.66	1768	2685	22.43
25 - 49	134	176	19.56	4763	7448	62.23
10 - 24	192	368	40.89	3360	10808	90.30
5 - 9	94	462	51.33	658	11466	95.80
2 - 4	143	605	67.22	429	11895	99.38
1	74	679	75.44	74	11969	100.00
0	221	900	100.00	0	--	--
TOTAL	900	900	0	11969	11969	100

Source: Hart [1976] Figure 1-11.

Table 4-6. Tornado Strike Distribution Within the United States

Twenty states recorded 1970 annual expected building damage rates for all hazards which were equal to or in excess of the aggregated national rate for all hazards [See Table 4-7]. Each of the states of the Gulf Coast were included in this group, as were four of the Atlantic seaboard and two of the Pacific coast states. Only nine of the interior, land-locked states were in this group, including: Colorado, Utah, South Dakota, Kansas, Missouri, Nebraska, Arkansas, Oklahoma and Iowa. In 1970 these twenty states claimed a total population of 81.98 million persons and represented a combined value of buildings in excess of $785 billion.

These same twenty states accounted for 54.6% of the nation's annual expected hazard-induced dollar losses to buildings in 1970 [See Table 4-10]. Also in 1970, fifteen states experienced an all-hazard annual expected building damage rate of 0.3% or higher. Containing a combined population of over 72 million persons, these "high" damage-rate states included: Florida (0.825%), Louisiana (0.721%), Mississippi (0.477%), Kansas (0.423%), Washington (0.404%), Texas (0.398%), Missouri (0.396%), Nebraska (0.391%), California (0.375%), Oklahoma (0.338%), Colorado (0.319%), South Dakota (0.311%), South Carolina (0.311%), North Carolina (0.310%), Alabama (0.309%).

STATE	ALL HAZARDS DAMAGE RATE	ALL HAZARDS RATIO TO NAT'L AVERAGE	ALL HAZARDS RANK	FLOOD DAMAGE RATE	FLOOD RATIO TO NAT'L AVERAGE	FLOOD RANK	STORM SURGE DAMAGE RATE	STORM SURGE RATIO TO NAT'L AVERAGE	STORM SURGE RANK	TSUNAMI DAMAGE RATE	TSUNAMI RATIO TO NAT'L AVERAGE	TSUNAMI RANK
FL	.825	2.96	1	.093	1.011	27	.319	14.930	1	0		
LA	.721	2.59	2	.125	1.355	12	.279	13.053	2	0		
MS	.477	1.71	3	.158	1.718	3	.090	4.231	3	0		
KS	.423	1.52	4	.134	1.460	6	0					
WA	.404	1.45	5	.086	.930	32	0			.002	4.622	4
TX	.398	1.43	6	.112	1.220	16	.015	.709	12	0		
MO	.396	1.42	7	.133	1.447	8	0			0		
NE	.391	1.40	8	.134	1.459	7	0					
CA	.375	1.35	9	.078	.847	39	0			.002	4.692	3
OK	.338	1.21	10	.115	1.251	15	0			0		
CO	.319	1.15	11	.081	.880	36	0			0		
SD	.311	1.12	12	.162	1.763	2	0			0		
SC	.311	1.12	12	.111	1.202	17	.036	1.671	5	0		
NC	.310	1.11	14	.105	1.135	19	.019	.901	10	0		
AL	.309	1.11	15	.108	1.173	18	.016	.749	11	0		
AR	.299	1.07	16	.147	1.596	4	0			0		
IA	.291	1.04	17	.141	1.532	5	0			0		
UT	.286	1.03	18	.083	.901	35	0			0		
RI	.284	1.02	19	.073	.794	40	.076	3.571	4	0		
CT	.284	1.02	19	.062	.676	47	.028	1.310	6	0		
ND	.277	.99	21	.167	1.810	1	0			0		
IL	.274	.98	22	.104	1.133	20	0			0		
MA	.272	.98	23	.064	.699	46	.020	.922	9	0		
IN	.252	.90	24	.127	1.375	11	0			0		
ME	.233	.84	25	.086	.929	33	.006	.282	17	0		
MI	.230	.83	26	.116	1.263	14	0			0		
GA	.223	.80	27	.093	1.007	28	.011	.515	14	0		
VA	.220	.79	28	.078	.850	38	.028	1.295	7	0		
NH	.220	.79	28	.072	.778	41	0			0		
MN	.215	.77	30	.129	1.405	9	0			0		
WI	.213	.76	31	.128	1.387	10	0			0		
TN	.210	.75	32	.100	1.089	21	0			0		
MT	.202	.73	33	.091	.984	29	0			0		
WY	.200	.72	34	.088	.950	30	0			0		
OH	.194	.70	35	.119	1.300	13	0			0		
KY	.192	.69	36	.099	1.077	22	0			0		
DE	.184	.66	37	.079	.857	37	.009	.412	15	0		
NM	.182	.65	38	.093	1.014	26	0			0		
ID	.179	.64	39	.094	1.017	25	0			0		
WV	.166	.60	40	.097	1.048	23	0			0		
NY	.166	.59	40	.055	.598	50	.022	1.019	8	0		
AK	.164	.59	42	.062	.668	48	0			.010	23.460	2
NJ	.159	.57	43	.059	.645	49	.014	.643	13	0		
MD	.155	.56	44	.065	.710	45	.008	.381	16	0		
NV	.153	.55	45	.071	.768	42	0			0		
OR	.151	.54	46	.094	1.021	24	0			.0005	1.173	5
VT	.137	.49	47	.084	.915	34	0			0		
PA	.136	.49	48	.070	.765	43	0			0		
AZ	.130	.47	49	.087	.945	31	0			0		
HI	.114	.41	50	.069	.749	44	0			.041	96.187	1
DC	.087	.31	51	.050	.543	51	0			0		
U.S.	.279			.092			.0214			.0004		

STATE	TORNADO DAMAGE RATE	TORNADO RATIO TO NAT'L AVERAGE	TORNADO RANK	HURRICANE DAMAGE RATE	HURRICANE RATIO TO NAT'L AVERAGE	HURRICANE RANK	SEVERE WIND DAMAGE RATE	SEVERE WIND RATIO TO NAT'L AVERAGE	SEVERE WIND RANK
FL	.068	1.595	10	.312	9.398	1	.0003	.548	32
LA	.044	1.030	20	.160	4.831	2	.0003	.603	31
MS	.058	1.349	11	.060	1.795	9	0		
KS	.150	3.523	2	0			.001	1.699	20
WA	.001	.026	49	0			.0006	1.023	24
TX	.089	2.095	6	.030	.889	15	.001	1.762	17
MO	.122	2.871	3	0			.0004	.804	27
NE	.086	2.017	7	0			.001	2.558	10
CA	.006	.141	43	0			.0004	.639	29
OK	.188	4.417	1	0			.002	3.161	6
CO	.041	.962	21	0			.002	3.654	4
SD	.055	1.283	13	0			.002	3.453	5
SC	.040	.945	22	.054	1.614	12	0		
NC	.032	.745	26	.082	2.477	6	.0005	.913	25
AL	.069	1.618	9	.045	1.355	13	0		
AR	.054	1.266	14	0			0		
IA	.072	1.691	8	0			.001	2.119	12
UT	.005	.111	45	0			.001	1.717	19
RI	.005	.126	44	.112	3.368	4	.002	3.928	2
CT	.016	.375	35	.125	3.765	3	.001	2.088	13
ND	.046	1.074	16	0			.002	3.800	3
IL	.120	2.815	4	0			.0006	1.151	22
MA	.056	1.306	12	.100	3.022	5	.001	2.302	11
IN	.098	2.292	5	0			.0008	1.498	21
ME	.012	.281	37	.076	2.286	8	0		
MI	.044	1.037	18	0			.0001	.201	35
GA	.045	1.055	17	.020	.602	18	0		
VA	.017	.408	33	.059	1.777	10	.0006	1.114	23
NH	.038	.887	24	.078	2.361	7	0		
MN	.054	1.262	15	0			.001	1.937	15
WI	.044	1.036	19	0			.0005	.895	26
TN	.032	.762	25	0			0		
MT	.006	.147	42	0			.002	2.850	9
WY	.016	.366	36	0			.003	5.709	1
OH	.039	.924	23	0			.0003	.512	33
KY	.031	.733	28	0			0		
DE	.025	.577	29	.032	.952	14	0		
NM	.024	.567	30	0			.001	2.010	14
ID	.006	.149	41	0			.002	2.887	8
WV	.007	.164	40	0			0		
NY	.005	.109	46	.056	1.698	11	.0004	.797	28
AK	0			0			0		
NJ	.031	.734	27	.028	.831	16	.001	1.746	18
MD	.018	.410	32	.026	.783	17	.0002	.365	34
NV	.003	.081	47	0			.002	3.142	7
OR	.002	.047	48	0			0		
VT	.021	.494	31	.005	.158	21	0		
PA	.017	.406	34	.014	.407	20	.0003	.621	30
AZ	.011	.258	38	0			0		
HI	0			0			.001	1.827	16
DC	.009	.211	39	.015	.452	19	0		
U.S.	.043			.033			.0005		

STATE	EARTHQUAKE DAMAGE RATE	EARTHQUAKE RATIO TO NAT'L AVERAGE	EARTHQUAKE RANK	LANDSLIDE DAMAGE RATE	LANDSLIDE RATIO TO NAT'L AVERAGE	LANDSLIDE RANK	EXPANSIVE SOIL DAMAGE RATE	EXPANSIVE SOIL RATIO TO NAT'L AVERAGE	EXPANSIVE SOIL RATE
FL	.002	.052	28	.0064	.357	49	.024	.621	27
LA	.006	.199	16	.0196	1.093	25	.087	2.250	5
MS	.003	.086	21	.0189	1.054	26	.090	2.328	4
KS	.001	.029	34	.0159	.886	34	.120	3.104	3
WA	.272	8.577	1	.0292	1.628	4	.013	.336	39
TX	.001	.0243	38	.0110	.613	42	.139	3.596	2
MO	.034	1.069	8	.0238	1.327	13	.083	2.147	6
NE	.001	.044	29	.0185	1.031	27	.149	3.854	1
CA	.193	6.081	2	.0162	.903	32	.080	2.069	7
OK	.002	.068	25	.0094	.524	44	.021	.543	30
CO	.089	2.804	5	.0276	1.539	6	.078	2.018	8
SD	.002	.060	27	.0247	1.377	10	.066	1.707	10
SC	.010	.306	13	.0164	.914	31	.044	1.138	18
NC	.0003	.008	41	.0244	1.360	11	.047	1.216	16
AL	0			.0172	.959	30	.054	1.397	13
AR	.024	.756	9	.0219	1.221	17	.052	1.345	14
IA	0			.0202	1.126	23	.057	1.474	12
UT	.115	3.626	3	.0295	1.645	2	.052	1.345	14
RI	.001	.034	32	.0065	.362	46	.008	.207	47
CT	.002	.072	24	.0294	1.639	3	.020	.517	31
ND	0			.0235	1.310	14	.039	1.009	21
IL	.0008	.025	37	.0262	1.461	7	.023	.595	26
MA	.003	.084	23	.0208	1.160	21	.008	.207	46
IN	.0002	.006	42	.0139	.775	37	.013	.336	39
ME	0			.0255	1.422	8	.028	.724	24
MI	.001	.031	33	.0214	1.193	19	.047	1.216	16
GA	.001	.038	31	.0123	.686	41	.041	1.061	20
VA	.0008	.026	35	.0183	1.020	29	.018	.466	33
NH	.003	.085	22	.0199	1.109	24	.009	.245	44
MN	0			.0146	.814	35	.016	.414	34
WI	0			.0253	1.411	9	.015	.388	35
TN	.049	1.544	6	.0065	.362	46	.022	.569	29
MT	.022	.689	11	.0184	1.026	28	.063	1.630	11
WY	0			.0222	1.238	16	.072	1.862	9
OH	.001	.039	30	.0206	1.148	22	.014	.362	36
KY	.005	.160	17	.0233	1.299	15	.034	.879	23
DE	.002	.057	27	.0279	1.555	5	.011	.285	43
NM	.013	.416	12	.0090	.502	45	.042	1.086	19
ID	.024	.750	10	.0160	.892	33	.038	.983	22
WV	.0007	.022	39	.0344	1.918	1	.027	.698	25
NY	.009	.277	14	.0128	.714	39	.006	.155	49
AK	.092	2.899	4	0			0		
NJ	.004	.128	18	.0128	.714	39	.009	.230	45
MD	.0002	.006	43	.0243	1.355	12	.014	.362	36
NV	.047	1.467	7	.0110	.613	41	.019	.491	32
OR	.009	.268	15	.0211	1.176	20	.025	.647	26
VT	0			.0142	.792	36	.012	.310	42
PA	.0003	.011	40	.0215	1.199	18	.013	.336	39
AZ	.004	.126	19	.0136	.758	38	.014	.362	36
HI	.003	.095	20	0			0		
DC	.001	.25	36	.0065	.362	46	.006	.155	48
U.S.	.032			.018			.039		

Table 4-7. Expected Hazard-induced Building Damage Rates, by State, for Nine Natural Hazards in 1970

HAZARD	NATIONAL BUILDING DAMAGE RATE (NBDR) (%)	1970 POPULATION AND VALUE OF BUILDINGS IN INDICATED CLASS*							
		(1) NBDR × 2		(2) NBDR × 1 OR GREATER		(3) 0.5 TO 0.99 × NBDR		(4) 0.0 TO 0.49 NBDR	
		POP.**	BUILDING VALUE***	POP.	BUILDING VALUE	POP.	BUILDING VALUE	POP.	BUILDING VALUE
FLOOD	.0921	-	-	113.35	1048.5	89.89	1016.0	--	--
STORM SURGE	.0214	13.60	115.3	42.11	448.3	37.17	359.0	123.96	1257.2
TSUNAMI	.0004	24.41	277.5	26.50	297.4	-	-	176.74	1767.1
TORNADO	.0426	38.50	383.3	88.01	840.1	37.16	350.9	78.07	873.5
HURRICANE	.0332	26.91	254.8	58.05	594.1	27.43	283.8	117.76	1186.6
SEVERE WIND	.0005	23.29	234.5	73.92	761.7	85.27	897.7	44.05	405.1
EARTHQUAKE	.0317	26.91	300.8	36.00	382.5	3.32	26.3	163.92	1655.7
LANDSLIDE	.0179	-	-	104.53	1031.0	85.43	905.8	13.46	127.7
EXPANSIVE SOILS	.0387	47.65	480.2	81.37	777.6	24.49	254.3	97.38	1032.6
ALL HAZARDS****	.2786	10.43	91.4	81.98	785.9	105.72	1119.2	15.54	159.4

Data source, see Table 4-7

*Population and building values of states which recorded indicated building damage rate
**Population in millions for affected states
***Building value in billions of dollars
****Population and building value determined using NBDR for all hazards

Table 4-8. Population at Risk of Exposure to Specific Building Damage Rates, by Hazard, 1970

BUILDING DAMAGE RATE	NUMBER OF STATES IN CLASS	TOTAL POPULATION OF CLASS*
1. LOW [<0.20]	17	65.62
2. MEDIUM [0.20 - 0.299]	19	65.43
3. HIGH [0.30 - 0.829]	15	72.19
TOTALS	51	203.24

Source: See Table 4-7. *millions

Table 4-9. Size of State Populations Exposed to Various Hazard-Induced Building Damage Rates in 1970

For the year 2000, state-level exposures to various building damage rates are expected to be as depicted in Table 4-11.

Although state-level aggregations of people and property certainly represent communities whose interests are affected by exposures to natural hazards, in most cases such aggregations do not provide a correct picture of the actual number of people and buildings which are directly exposed to a given hazard or combination of hazards. Accordingly, the study tallied and rank-ordered U.S. counties by their 1970 building damage rates. In that year, five hundred U.S. counties

1970 BASELINE % DAMAGE	STATE	TOTAL STRUCTURE VALUE ($BILL.)	POPULATION (MILLIONS)	EARTH HAZARDS			WATER HAZARDS			WIND HAZARDS			ALL HAZARDS
				EQ	ES**	LS	FL*	SS	TS	TO	HU	SW	
.309	AL	26.7	3.44	.0	14.45	4.6	28.9	4.3	0	18.4	11.9	0	82.6
.164	AK	3.9	0.27	3.6	0	0	2.4	0	0.4	.0	0	0	6.4
.130	AZ	16.9	1.77	0.7	2.3	2.29	14.7	0	0	1.9	0	0	21.9
.299	AR	13.6	1.92	3.3	7.01	2.98	20.0	0	0	7.3	0	0	40.6
.375	CA	226.0	19.96	439.6	182.59	36.83	178.5	0	3.5	13.8	0	0.8	855.6
.319	CO	22.7	2.21	20.2	17.77	6.27	18.4	0	0	9.4	0	0.4	72.3
.284	CT	35.0	3.03	0.8	7.08	10.30	21.8	9.7	0	5.7	43.6	0.4	99.4
.184	DE	5.7	0.55	0.1	.64	1.59	4.5	0.5	0	1.4	1.8	0	10.5
.087	DC	12.6	0.76	0.1	.79	.82	6.3	0	0	1.1	1.9	0	11.0
.825	FL	61.1	6.79	1.0	14.60	3.91	56.9	195.0	0	41.8	190.4	0.2	503.8
.223	GA	41.5	4.59	0.5	17.17	5.12	38.5	4.4	0	18.6	8.4	0	92.7
.114	HI	10.0	0.77	0.3	0	0	6.9	0	4.1	.0	0	0.1	11.4
.179	ID	6.3	0.71	1.5	2.42	1.01	5.9	0	0	0.4	0	0.1	11.3
.274	IL	126.8	11.12	1.0	28.69	33.16	132.2	0	0	152.2	0	0.8	348.0
.252	IN	48.8	5.20	0.1	6.31	6.80	61.8	0	0	47.7	0	0.4	123.1
.291	IA	25.8	2.83	.0	14.69	5.21	36.4	0	0	18.6	0	0.3	75.2
.423	KS	21.5	2.25	0.2	25.88	3.41	28.9	0	0	32.3	0	0.2	90.9
.192	KY	25.6	3.22	1.3	8.58	5.96	25.4	0	0	8.0	0	0	49.2
.721	LA	30.3	3.64	1.9	26.29	5.95	37.8	84.5	0	13.3	48.6	0.1	218.4
.233	ME	8.3	0.99	.0	2.30	2.12	7.1	0.5	0	1.0	6.3	0	19.3
.155	MD	49.2	3.92	0.1	6.66	11.97	32.2	4.0	0	8.6	12.8	0.1	76.4
.272	MA	63.4	5.69	1.7	4.83	13.21	40.8	12.5	0	35.3	63.6	0.8	172.7
.230	MI	90.8	8.88	0.9	42.31	19.47	105.6	0	0	40.1	0	0.1	208.5
.215	MN	37.7	3.80	.0	5.87	5.52	48.8	0	0	20.3	0	0.4	80.9
.477	MS	14.6	2.22	0.4	13.19	2.76	23.1	13.2	0	8.4	8.7	0	69.7
.396	MO	45.1	4.68	15.3	37.22	10.75	60.1	0	0	55.2	0	0.2	178.8
.202	MT	6.4	0.69	1.4	4.02	1.18	5.8	0	0	0.4	0	0.1	12.9
.391	NE	14.3	1.49	0.2	21.33	2.64	19.2	0	0	12.3	0	0.2	55.9
.153	NV	5.8	0.49	2.7	1.12	.64	4.1	0	0	0.2	0	0.1	8.9
.220	NH	7.4	0.74	0.2	.70	1.47	5.3	0	0	2.8	5.8	0	16.3
.159	NJ	83.7	7.17	3.4	7.47	10.70	49.7	11.5	0	26.2	23.1	0.8	132.9
.182	NM	9.1	1.02	1.2	3.81	.82	8.5	0	0	2.2	0	0.1	16.6
.166	NY	229.6	18.24	20.2	14.76	29.36	126.5	50.0	0	10.7	129.4	1.0	381.9
.310	NC	40.0	5.08	0.1	18.92	9.76	41.8	7.7	0	12.7	32.	0.2	124.1
.277	ND	4.8	0.62	.0	1.88	1.13	8.0	0	0	2.2	0	0.1	13.3
.194	OH	106.3	10.66	1.0	14.57	21.87	126.8	0	0	41.9	0	0.3	206.4
.338	OK	23.1	2.56	0.5	4.86	2.16	26.6	0	0	43.5	0	0.4	78.0
.151	OR	19.9	2.09	1.7	4.97	4.19	18.7	0	0.1	0.4	0	0	30.1
.136	PA	116.1	11.80	0.4	14.84	24.91	81.8	0	0	20.1	15.7	0.4	158.2
.284	RI	9.3	0.95	0.1	.74	.60	6.8	7.1	0	0.5	10.4	0.2	26.4
.311	SC	19.6	2.59	1.9	8.66	3.21	21.7	7.0	0	7.9	10.5	0	60.9
.311	SD	5.3	0.67	0.1	3.49	1.31	8.6	0	0	2.9	0	0.1	16.5
.210	TN	30.8	3.92	15.1	6.67	2.00	30.9	0	0	10.0	0	0	64.7
.398	TX	103.7	11.20	0.8	143.69	11.36	116.5	15.7	0	92.6	30.6	1.0	412.3
.286	UT	10.6	1.06	12.2	5.53	3.13	8.8	0	0	0.5	0	0.1	30.3
.137	VT	3.8	0.44	.0	.44	.54	3.2	0	0	.8	0.2	0	5.2
.220	VA	48.8	4.65	0.4	8.87	8.94	38.2	13.5	0	8.5	28.8	0.3	107.5
.404	WA	35.6	3.41	96.9	4.71	10.41	30.5	0	0.7	.4	0	0.2	143.8
.166	WV	14.2	1.74	0.1	3.87	4.88	13.7	0	0	1.0	0	0	23.6
.213	WI	41.2	4.42	.0	6.28	10.43	52.6	0	0	18.2	0	0.2	87.7
.200	WY	3.2	0.33	.0	2.27	.71	2.8	0	0	0.5	0	0.1	6.4
.279	U.S.	2064.5	203.24	655.2	798.1	370.3	1901.0	441.1	8.8	880.2	685.4	11.3	5751.4

*Flood is estimated with a different model

**Only residential expansive soil losses

Table 4-10. Damage to Buildings (In Millions of Dollars) by State for the Year 1970

HAZARD	NATIONAL BUILDING DAMAGE RATE (NBDR) PERCENT	2000 POPULATION AND VALUE OF BUILDINGS IN INDICATED CLASS							
		(1) NBDR X 2		(2) NBDR X 1 AND GREATER		(3) 0.5 TO 0.99 X NBDR		(4) 0.0 TO 0.49 x NBDR	
		POP**	BUILDING VALUE***	POP.	BUILDING VALUE	POP.	BUILDING VALUE	POP.	BUILDING VALUE
FLOOD	.0324	--	--	118.80	2163.9	137.30	2761.3	--	--
STORM SURGE	.0239	19.02	318.6	26.27	449.2	71.09	1423.8	158.74	3052.2
TSUNAMI	.0004	31.47	653.1	31.47	653.1	2.49	45.1	222.14	4227.0
TORNADO	.0418	45.52	870.0	110.26	2024.7	47.40	855.9	98.44	2044.6
HURRICANE	.0354	36.74	657.6	75.48	1447.9	30.36	607.9	150.26	2869.4
SEVERE WIND	.0005	23.35	453.1	87.90	1708.6	101.08	1995.0	67.12	1221.6
EARTHQUAKE	.0239	34.61	710.2	45.89	909.1	3.65	58.2	206.56	3957.9
LANDSLIDE	.0177	--	--	126.18	2387.9	109.19	2160.9	20.73	376.4
EXPANSIVE SOIL	.0202	59.11	1135.7	99.63	1836.6	48.89	901.5	107.58	2187.1
ALL HAZARDS ****	.1961	15.52	265.2	117.96	2225.9	117.96	2196.3	26.38	503.0

*Population and building values of states which recorded indicated building damage rate
**Population in millions for affected states
***Building value in billions of dollars
****Population and building value determined using NBDR for all hazards

Table 4-11. Population at Risk of Exposure to Specified Building Damage Rates, by Hazard, Year 2000.

experienced building damage rates of 0.287% or higher as a result of their exposure to all hazards, except riverine flooding [See Table 4-12].

CATEGORY, BY ANNUAL PERCENT OF BUILDING VALUE EXPECTED TO BE LOST** (PERCENT)	NUMBER OF COUNTIES IN CATEGORY		BUILDING WEALTH AT RISK (BILLIONS)		EXPECTED ANNUAL BUILDING LOSSES (MILLIONS)		POPULATION AT RISK (MILLIONS)		EXPECTED ANNUAL PER CAPITA LOSSES ($)
	N	CUM	N	CUM	N	CUM	N	CUM	
3.00+ %	2	2	$ .308	$ .308	$ 10.72	$ 10.72	.049	.049	$218.37
2.50 - 2.99%	0	2	-	.308	-	10.72	-	.049	-
2.00 - 2.49%	1	3	.422	.730	9.92	20.64	.053	.102	188.54
1.75 - 1.99%	3	6	1.247	1.977	23.42	44.06	.189	.290	124.24
1.50 - 1.749%	2	8	.094	2.071	1.54	45.60	.012	.302	128.98
1.25 - 1.49%	11	19	9.332	11.403	126.13	171.73	.958	1.260	131.65
1.00 - 1.249%	9	28	22.557	33.960	267.93	439.66	2.133	3.393	125.62
0.75 - 0.999%	29	57	26.040	60.000	222.00	661.66	2.508	5.901	88.53
0.50 - 0.749%	39	96	46.029	106.029	270.75	932.41	4.816	10.717	56.22
0.40 - 0.499%	64	160	84.346	190.375	371.37	1303.78	7.673	18.389	48.40
0.30 - 0.399%	251	411	206.371	396.747	670.31	1974.09	19.418	37.807	34.52
<0.30%	89	500	33.518	430.264	98.26	2072.35	3.623	41.430	27.12

*All study hazards, except riverine flooding
**Range is 0.287 to 3.51%

Table 4-12. Distribution of Most Damage-Prone Counties of the U.S., Classified by Expected Annual Losses and by Annual Proportion of Building Value Expected to be Lost Through Exposure to Eight Natural Hazards*, 1970

Containing 20.4% of the nation's population and 20.8% of its building wealth, these counties accounted for 36% of the nation's annual expected dollar loss from building damage in 1970. In these counties the annual expected proportion of building value which was lost in 1970 as a result of non-riverine hazard-induced damages ranged from a low of 0.287% to a high of 3.51%, and the ratio of county building damage rates to the national rate ranged from 1.47 to 18.00. [See Table 4-13.]

COUNTY	DAMAGE* RATE	RANK	** INDEX	VALUE AT RISK (MILLIONS)	EXPECTED ANNUAL LOSS	POPULATION (1000'S)	EXPECTED ANNUAL PER CAPITA LOSS
1. STODDARD, MO	.0351	1	18.00	$ 161.0	$ 5,651,100	25.7	$219.89
2. IBERIA, LA	.0186	5	9.53	380.0	7,068,000	57.4	123.14
3. COLLIER, FL	.0144	10	7.38	306.0	4,406,400	38.0	115.96
4. WASHINGTON, NC	.0109	25	5.59	88.8	967,920	14.0	69.14
5. ST. LUCIE, FL	.00784	50	4.02	408.0	3,198,720	50.8	62.97
6. MANATEE, FL	.00483	100	2.48	576.0	2,782,080	97.1	28.65
7. REFUGIO, TX	.00368	200	1.87	61.9	227,792	9.5	24.00
8. MURRAY, OK	.00332	300	1.70	79.0	262,280	10.7	24.51
9. SANGAMON, IL	.00303	400	1.55	2060.0	6,241,800	161.0	38.77
10. GRADY, OK	.00287	500	1.47	217.0	622,790	29.4	21.18

*Does not include riverine flooding
**County damage rate ÷ national average building damage rate for 1970 for all hazards except riverine flooding (.00195).

Table 4-13. Expected Total Annual and Annual Per Capita Building Losses From Exposure to Eight Natural Hazards* in a Selected Subset of the 500 Most Damage-Prone Counties in the U.S., 1970

The geographic distribution of high damage rate counties and states is shown in Figure 4-5 to 4-11. Particularly striking in Figure 4-5 is the cluster of counties vulnerable to storm surge and hurricane winds along the shores of the Gulf Coast and Atlantic Ocean, as well as the almost unbroken belt of tornado-prone counties along the interior and middle sections of the United States. [See Figure 4-6.]

Although the county aggregated data depicted in Tables 4-12 and 4-13 suggest the steep gradient of natural hazard risk to which various population subsets are exposed, an even clearer picture is revealed by an examination targeted on specific hazard zones or areas, rather than the whole counties in which such areas are located.

For example, building damage rates from exposures to storm surge in coastal county areas which are within the surge-prone zone (0 ft. to 20 ft. adjusted mean sea

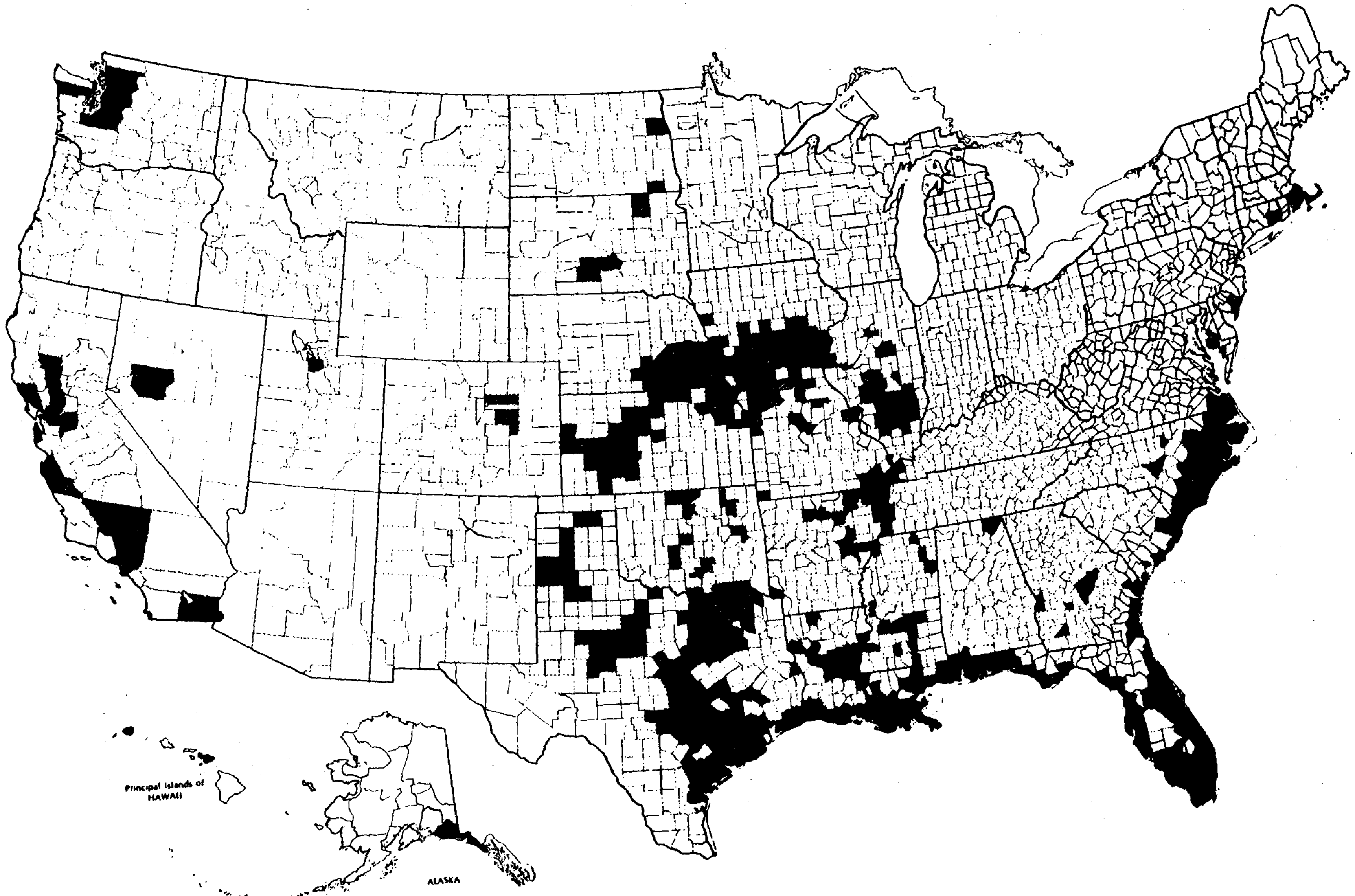


Figure 4-5. Map of High Damage Rate Counties for Eight Natural Hazards, 1970

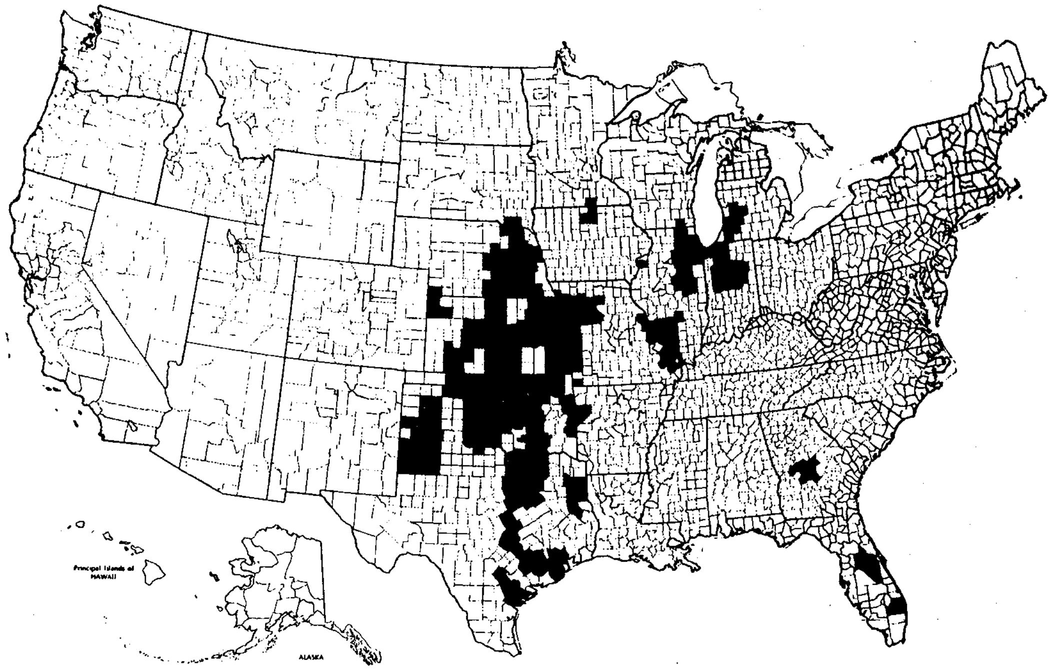


Figure 4-6. Counties with a Damage Rate Two or More Times the NBDR for Tornado, 1970

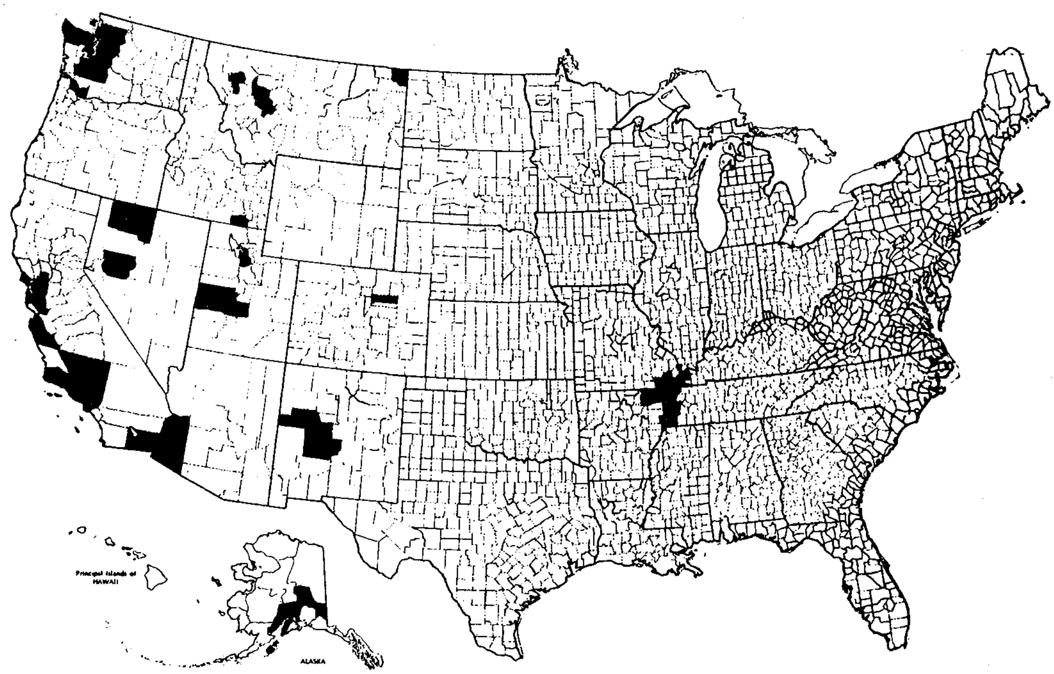


Figure 4-7. Counties with a Damage Rate Two or More Times the NBDR for Earthquake, 1970

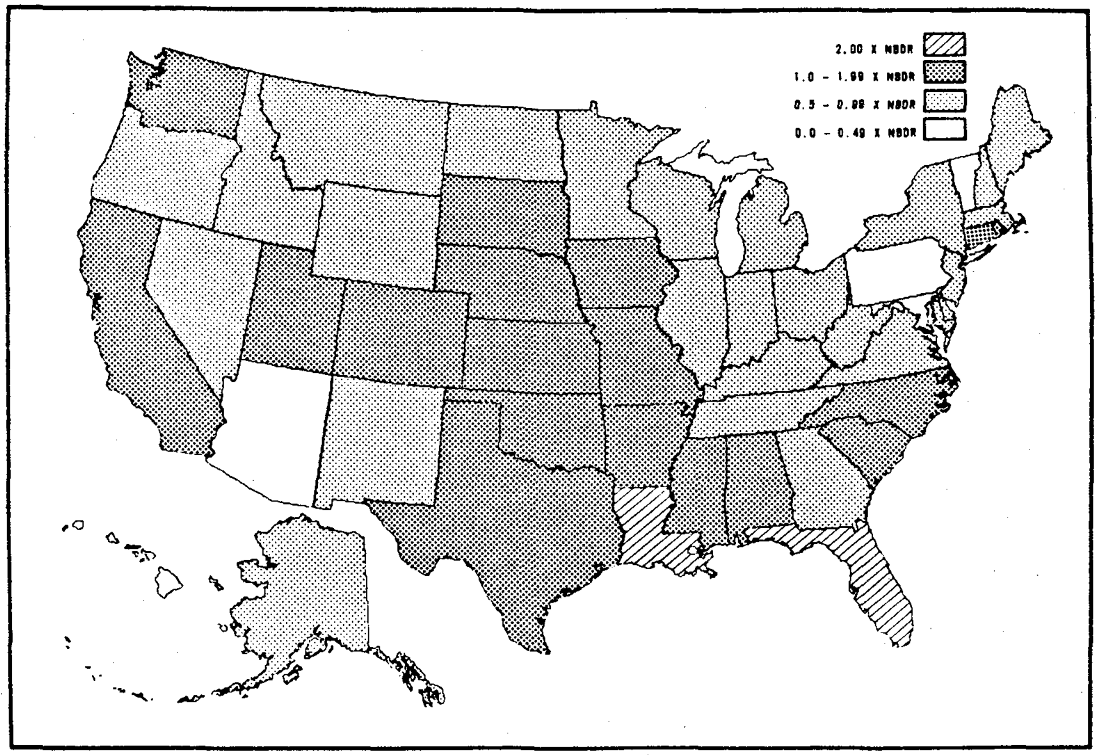


Figure 4-8. Ratio of State Building Damage Rate to the National Building Damage Rate (NBDR) for All Hazards, 1970

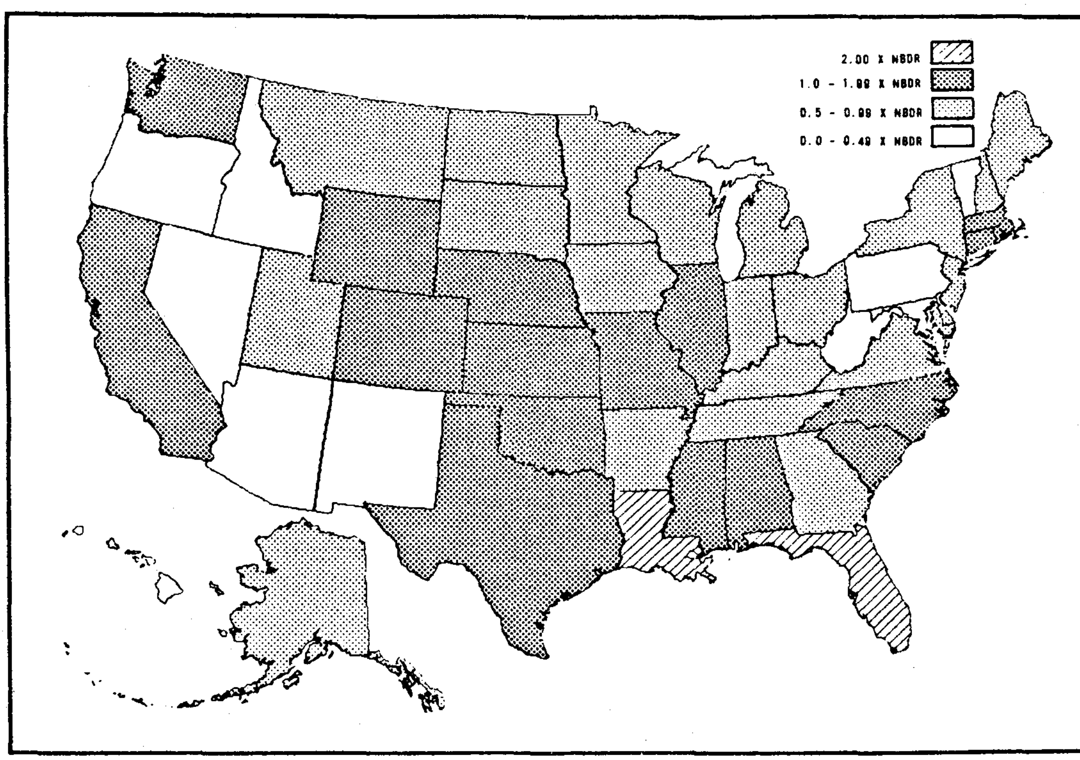


Figure 4-9. Ratio of State Building Damage Rate to the National Building Damage Rate (NBDR) for All Hazards, 2000

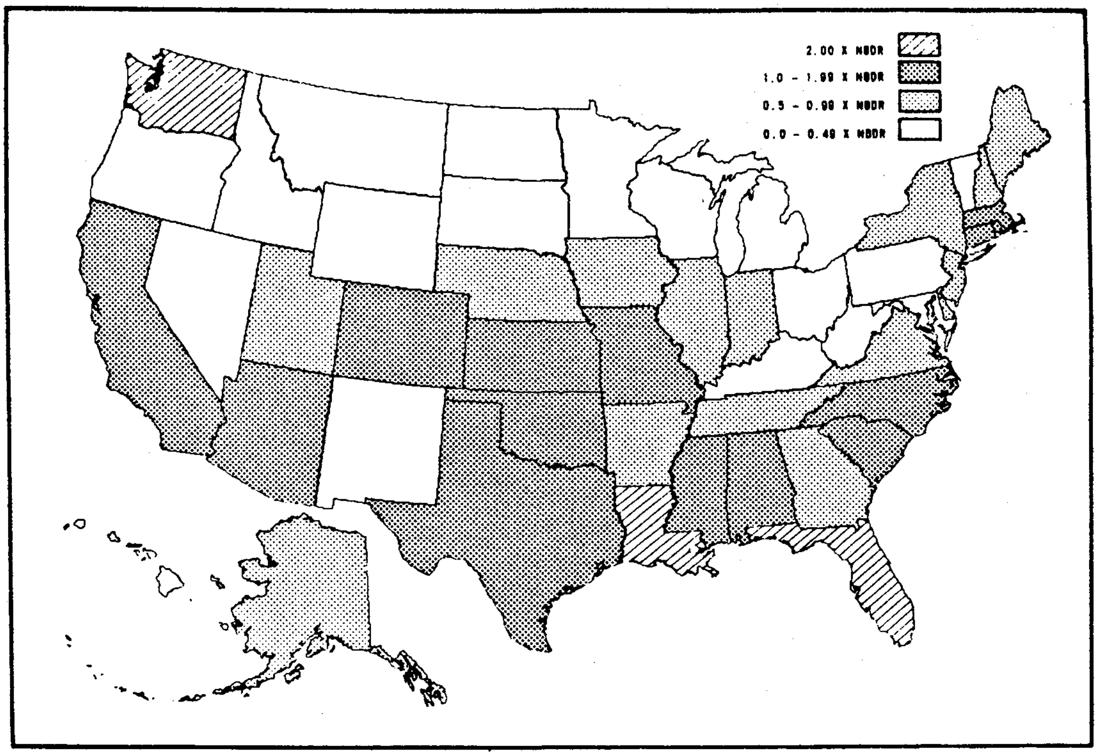


Figure 4-10. Ratio of State Building Damage Rate for Earthquake, Storm Surge, Tornado and Hurricane, to the NBDR, 1970

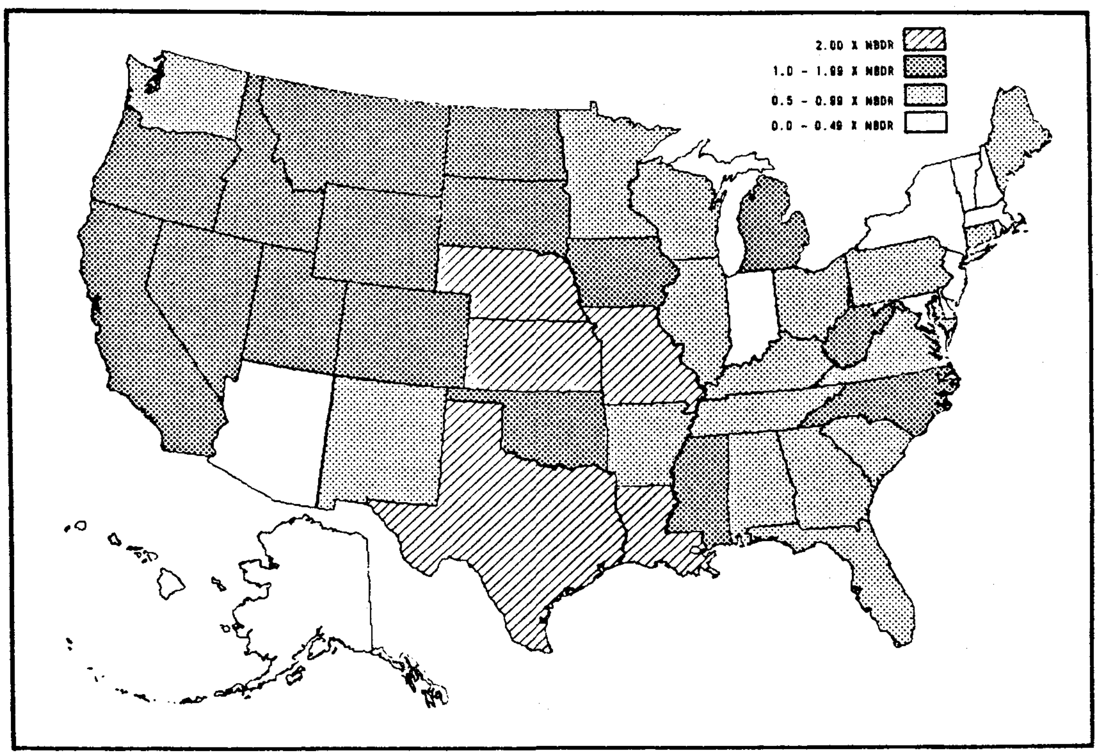


Figure 4-11. Ratio of State Building Damage Rate for Earthquake, Storm Surge, Tornado and Hurricane, to the NBDR, 2000

level), range from 0.025% per year in coastal counties of New Hampshire to 1.429% in the coastal counties of Mississippi [See Table 4-14], and annual per capita losses per exposed person range from $2.98 in New Hampshire to $121.37 in Georgia.

STATE	POPULATION	BUILDING WEALTH ($ MILLION)	ANNUAL EXPECTED LOSS ($ MILLION)	BUILDING DAMAGE RATE (%)	ANNUAL EXPECTED PER CAPITA LOSS ($)
1. MISSISSIPPI	116,924	922.18	13.178	1.4290	112.71
2. GEORGIA	35,883	312.68	4.355	1.3928	121.37
3. FLORIDA	2,467,506	22,720.49	195.271	0.8595	79.14
4. ALABAMA	78,774	593.82	4.323	0.7280	54.88
5. LOUISIANA	1,664,001	15,000.57	84.482	0.5632	50.77
6. RHODE ISLAND	135,288	1,321.94	7.075	0.5352	52.30
7. N. CAROLINA	269,991	1,895.59	7.723	0.4074	28.61
8. TEXAS	408,987	4,142.19	15.725	0.3797	38.45
9. MASSACHUSETTS	297,700	3,490.19	12.635	0.3620	42.44
10. CONNECTICUT	257,364	2,854.71	9.684	0.3392	37.63
11. SO. CAROLINA	336,588	2,828.94	6.999	0.2474	20.79
12. MAINE	26,370	236.64	0.527	0.2227	19.98
13. DELAWARE	25,770	268.91	0.536	0.1993	20.80
14. NEW YORK	1,926,873	27,456.65	50.049	0.1823	25.97
15. VIRGINA	877,110	8,763.71	13.547	0.1546	15.45
16. NEW JERSEY	689,514	8,271.66	11.406	0.1379	16.54
17. MARYLAND	314,715	3,462.94	4.044	0.1168	12.85
18. N. HAMPSHIRE	10,743	126.44	0.032	0.0253	2.98
TOTALS	9,940,101	104,670.25	441.591	0.4219	44.43

Source: Calculated from data presented in Lee, et.al. (1976) Figure 3-9, Tables 3-2, 3-3 and Appendix A

Table 4-14. Population Levels, Building Exposures, Building Damage Rates and Building Losses From Storm Surge in Areas of 0-20' AMSL, 1970

Of course, in any given storm surge hazard area (where storm frequencies are held constant), these damage rates and annual per capita losses will vary markedly throughout the exposure zone, with persons and property at lower elevations experiencing much higher rates and per capita losses than those at higher elevations.

Similarly, riverine flood losses in 1970 also exhibited a steep gradient in annual expected building damage rates [See Tables 5-3, 5-23(b), and 5-25] and in annual per capita losses (for all types of buildings) by type of exposure area, as follows:

RIVERINE FLOOD EXPOSURE AREA	BUILDING DAMAGE RATE	EXPOSED POPULATION	PER CAPITA ANNUAL LOSS $
1. FLOOD ZONE A UNPROTECTED COMMUNITIES	2.78%	805,730	$799.75
2. FLOOD ZONE B UNPROTECTED COMMUNITIES	1.20%	895,241	$349.59
3. FLOOD ZONE C UNPROTECTED COMMUNITIES	0.58%	1,193,654	$173.20
4. FLOOD ZONE A PROTECTED COMMUNITIES	0.46%	860,378	$132.42
5. FLOOD ZONE B PROTECTED COMMUNITIES	0.29%	955,960	$ 83.42
6. FLOOD ZONE D UNPROTECTED COMMUNITIES	0.22%	1,462,187	$ 64.53
7. FLOOD ZONE C PROTECTED COMMUNITIES	0.21%	1,274,614	$ 41.93
8. FLOOD ZONE E ALL FLOOD-PRONE COMMUNITIES	0.11%	3,312,216	$ 33.55

Table 4-15. Riverine Flood Exposure Areas, Building Damage Rate, Exposed Population and Per Capita Annual Loss

Comparable 1970 data for 500 year tsunami inundation areas are as indicated below. All data have been derived from Lee, et. al. (1976) and building wealth has been distributed to the inundation area in the same proportion as population:

VARIABLE	COUNTIES OF WHICH INUNDATION AREAS ARE LOCATED	INUNDATION AREAS, ONLY
POPULATION	18,200,851	237,500
BUILDING WEALTH ($ MILLION)	217,327.4	2,802.219
BUILDING DAMAGE LOSS ($ MILLION)	8.7	8.7
BUILDING DAMAGE RATE (%)	0.0040%	0.3105%
PER CAPITA BUILDING DAMAGE LOSS	$0.48	$36.63

Table 4-16. Inundation Areas, Building Damage Rate, Exposed Population and Per Capita Annual Loss

Those counties which are located in the eleven map grids (1°x1°) in which mean annual tornado strikes total 75 or more, exhibited an annual 1970 tornado-related building damage rate of between .225 and .261 percent and an annual per capita tornado-related building damage loss of $20 to $24.

Natural Hazard Losses in the United States

Hazardous natural occurrences apparently have been ubiquitous throughout the history of the United States, conspicuous sources of life loss and property damage, and the target of considerable public concern.

Twenty-one years before the adoption of the Declaration of Independence, earthquakes shattered Massachusetts and, during the height of the War of 1812, the highest magnitude earthquakes in the history of the nation left parts of Missouri and Arkansas a permanent "sunken country." [Dacy and Kunreuther, 1969]. In the immediate post-civil war years, another devastating earthquake struck South Carolina [Insurance Information Institute], and a forest fire consumed Peshtigo, Wisconsin in 1871, causing the deaths of 1182 persons [National Safety Council, 1971].

When the U.S. population moved westward from their original Atlantic colonies, they encountered the tornadoes of the Great Plains and Midwest States and the term, "storm cellar" or "cyclone cellar" became a permanent addition to the national vocabulary. In the open country of Kansas and similar states, the typical early homebuilding family constructed both a regular cellar under their permanent home and an "...additional cavelike cellar, commonly known as a 'cyclone cellar'...a few yards from the house. Such a cellar served for storage purposes; and also as protection for the family against the storms that swept across the open prairies. Lightning rods (invented in 1749 by Benjamin Franklin) were standard fixtures..." on houses [Beyer, 1968, pg. 31]. In spite of these safeguards, then as now, tornadoes claimed dozens of lives each year; but other hazards produced more calamitous single events.

In 1889, high and turbulent floodwaters claimed 2,209 lives in Johnstown, Pennsylvania on a single day, and eleven years later, the largest civil disaster in U.S. history occurred when a "great" hurricane pushed the waters of a storm surge over

Galveston, Texas (September 8, 1900) and thereby caused the deaths of 6,000 persons. Only six years later (April 18, 1906), a "great" earthquake rocked San Francisco and, together with the fires which were produced by the event, caused the death of 500-700 persons and more than $374 million in property damage. In September, 1928, a Florida hurricane caused 1,833 deaths over a two-day period; the previous March a California dam collapse sent a wall of water over an unwary populace and swept 450 individuals to their deaths [Insurance Information Institute, 1971; and National Safety Council, 1971].

Many of these pre-1930 natural disasters rank among the most severe civil calamities in our history, claiming more lives per event than the sinking of the Titanic in 1912 (1,517 lives lost), the Texas City ship explosion of 1947 (561 lives lost), the Cocoanut Grove nightclub fire of 1942 (492 lives lost), the Monongha, West Virginia coal mine explosion of 1907 (361 lives lost) [National Safety Council, 1971], and the worst air traffic accident in history in March 1977 (581 lives lost) [World Almanac and Book of Facts, 1978].

In more recent years, the Palm Sunday tornadoes of 1965 claimed 271 lives in five states; Hurricane Camille (1969) destroyed over 1.4 billion dollars in property and caused 256 deaths, the South Dakota Flash Flood of 1972 killed 236 persons, the Alaska Earthquake (1964) claimed 131, and Agnes - the hurricane and tropical storm of 1972 - caused 118 deaths and the loss of more than 3.1 billion dollars in property. Also, on a single day in 1974, tornadoes caused the deaths of 318 persons in several southern and midwestern states.

Less dramatic, but unquestionably of high cost in property damage, have been the week-by-week, and year-by-year damage losses produced by such hazards as expansive soils and land subsidence and by such events as landslides and the erosion of river banks, lake, and seashores. Periodic draughts, hail, ice, and snow storms also have taken their annual toll.

Numerous analysts have attempted to measure the annual magnitude, geographic distribution, short and long-term impacts of natural hazard exposure in the United States. Although most have focused on single hazards or related clusters of hazards, a few comprehensively oriented assessments have been published, and for at least sixteen natural hazards, various estimates of annual losses are available.

In 1969, one team of analysts estimated that the forty-year costs (1925-1965) of hurricanes, floods, tornadoes and earthquakes had reached 21,467 million dollars (in 1964 constant dollars) and 15,768 deaths to human beings [Dacy and Kunreuther, 1969].

In 1975, another team of researchers estimated that direct property losses from fifteen natural hazards equalled $23 per capita, or 0.05% of per capita income [White and Haas, 1975]. The hazards inventoried were avalanche, coastal erosion, drought, earthquake, flood, frost, hail, hurricane, landslide, lightning, tornadoes, tsunami, urban snow, volcano, and windstorm. Another set of authors has placed annual losses for expansive soils at 2.3 billion dollars per year, or about $11 per capita [Jones and Holtz, 1973].

Other authors have focused on the distribution of impacts among hazard-exposed populations. Thus, Bates [1963], and Cochrane [1975], have examined the distribution and impacts of hazard losses within the populations of communities that have experienced major natural disasters. From these studies a consistent finding has emerged: the persons most adversely affected are the poor, the elderly, and members of minority groups. Thus, in Bates' study, the most severe effects of a hurricane on the population of a Louisiana parish were found to be concentrated among the community's black population. Nearly half of the black population was killed in the disaster, but only 4% of the whites were so affected. Similarly, Cochrane's examination of eight communities which had experienced disasters revealed that "the lower income groups consistently bear a disproportionate share of the losses: they receive, in most instances, the smallest proportion of disaster relief; they are the least likely to be insured...; and they live in dwellings which are of the poorest construction and most subject to damage." Also, the elderly consistently are over-represented among the dead and injured of disaster-struck communities.

Whether or not the occurrence of a disaster has long-term effects on the economic vitality of a community has been examined by a number of investigators, including Dacy and Kunreuther [1969]; Haas, Kates, and Bowden [1977]; and Rossi, Wright, Wright, and Weber-Burdin [1978]. Surprisingly, the findings of these individuals have answered this question in the negative. Thus, the first group [Dacy and Kunreuther] concluded that a community actually "may benefit economically from a disaster through a rapid inflow of capital for rebuilding purposes and the adoption of technological innovations to meet crisis situations." Haas and his team concluded that pre-disaster trends, rather than the impacts of the disaster itself, determine the future fortunes of a community. "Simply stated, rapidly-growing cities recover rapidly; stable, stagnant or declining cities recover slowly and may have their decline accelerated." In the Wright-Rossi study, a sophisticated analysis of data for 1612 counties which had experienced flood, hurricane, or tornado damage between 1960 and 1970 failed to find any "consistent and significant" effects of such disaster occurrences.

Our study differed in several significant ways from the other investigations. First of all, it did not seek to tally the losses inventoried over any given time frame by field investigators in past disaster reports. Instead, it utilized a probabilistic approach which resulted in the generation of annual estimates of losses which may be expected to occur over a very large time frame as a result of both frequent and infrequent hazardous occurrences [See Chapter III]. This approach of course, required the use of several sets of data, respectively concerned with such subjects as: (1) the vulnerability of exposed building mixes to a range of hazard and hazard intensities; (2) the geographic distribution of specific hazards; (3) the probability of hazard occurrence, by intensity level, in specific hazard exposure areas or types of areas. Although comprehensive in its approach and treatment of natural hazard exposure, the study nonetheless fell short of fully expressing all of the major probable natural hazard losses in the United States. Thus, the study focused on only nine hazards and did not consider such major sources of loss as non-riverine flash flooding, headwater flooding, shore erosion, drought, forest, field and grass fires, hail, snow, and ice storms, and subsidence. Also, the study did not attempt to inventory such important potential losses as damage to automobiles, boats, ornamental vegetation, agricultural crops, and community infra-structures (streets, sidewalks, utility lines, etc.). Although focusing, in part, on potential expansive soil losses, the study did not consider possible expansive soil damage to structures other than detached-one and two-unit residences. This omission was borne, not of oversight, but of a paucity of empirical data necessary to the development of supportable damage algorithms. Finally, the riverine flood parts of the study are limited to a urban-oriented model in which the number of flood-prone cities in the U.S. was assumed to range from 5539 to 6455 between 1970 and 2000. However, by mid-1976 more than 14,000

U.S. communities had, in fact been identified by the Federal Insurance Administration as flood-prone. Thus, the study understates the real magnitude of natural hazard losses in the United States.

Nonetheless, the use of the study procedures discussed in Chapter III still resulted in the finding that natural annual expected losses arising from exposure to the nine study hazards totaled $8094 million in 1970. To be added to these mounting annual losses are those which have been increased by the values, additional costs to study, to predict, control the occurrence of, or to ameliorate the consequences of hazardous natural occurrences of both public and private hazard-mitigation measures. Substantial public investments have been poured into the construction of dams, levees, sea walls, floodway improvements and their investment probably have been equalled by private investment in improved building and site projects within other areas protection facilities. In 1973, federal expenditure from all sources for disaster relief are estimated to have totalled $2.5 billion [Rossi, Wright, et. al., 1978].

As shown in Table 4-1, the geographic distribution and vulnerability levels of buildings in that year resulted in annual expected total economic losses of $8094 million for all hazards and an annual expected yield of 979 deaths, 113,884 housing units lost, 129,850 person-years of homelessness, and 79,799 person-years of unemployment. In descending order of importance, the death-inducing hazards were: tornado (392), earthquake (273), riverine flood (190), hurricane (62), storm surge (37), tsunami (20), and severe wind (5). It is these same comparatively low probability but high-consequence hazards which result in the collapse of buildings and therefore in significant destruction of housing units and in the related production of homelessness and unemployment.

Also in descending order of importance, the nine natural hazards examined in this study were responsible for total dollar losses as follows: riverine flooding ($2,758.3 million), tornado ($1,656.0 million), hurricane ($1,056.0 million), expansive soil (798.1 million), earthquake (781.1 million), storm surge ($641.2 million), landslide ($370.3 million), severe wind ($18.0 million), and tsunami ($15.0 million). Damage to buildings accounted for over 71% of all annual expected dollar losses in 1970, while income loss and damage to building contents accounted for 5.2% and 23.66%, respectively of all losses [See Figure 4-12]. In the case

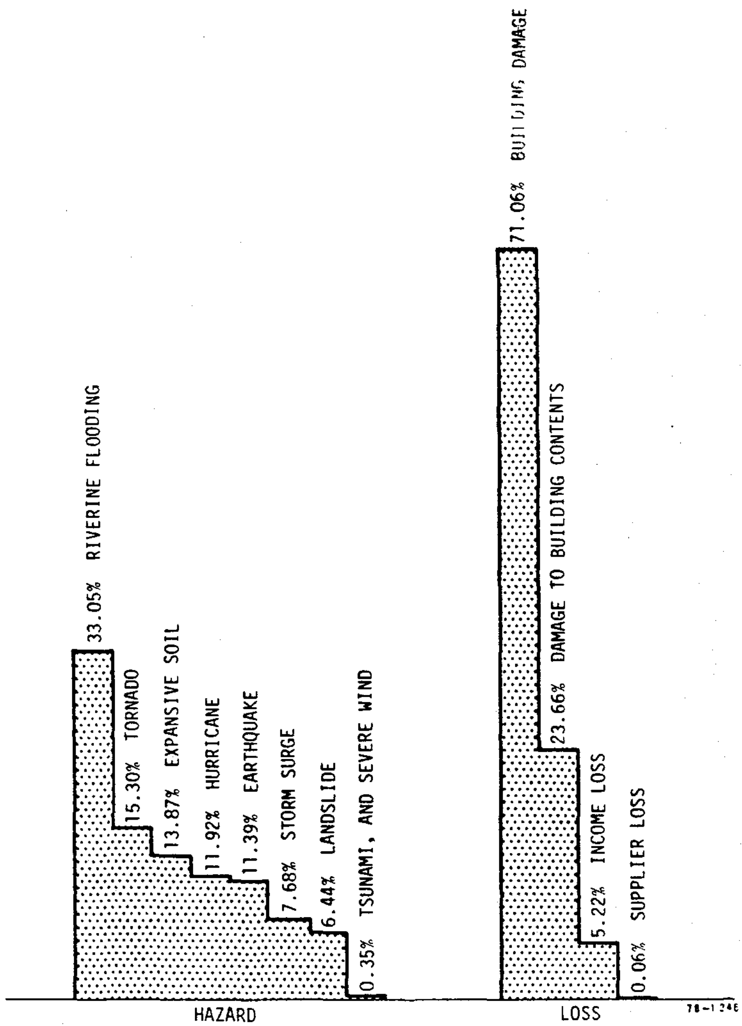


Figure 4-12. Proportion of 1970 Natural Hazard Annual Expected Dollar Losses Produced by Each Type of Hazard and by Each Type of Loss

of six hazards, damage to housing structures accounted for 58.8% of all non-riverine caused building losses; damage to all governmental structures produced 10.77% of such losses, and damage to transportation and utility structures yielded 9.7% of such losses [See Table 4-17]. As noted above, expansive soil losses in this study were confined exclusively to detached single-and double-unit housing structures.

Annual expected total dollar losses in 1970 for exposure to all nine natural hazards averaged $39.76 per capita and were equivalent to 1.00% of national per capita income. [See Table 4-18]. Building losses from all hazards were equal to .279% of the value of all buildings, [See Table 4-7]. However, as noted in the preceding section, both annual per capita hazard costs and building damage rates

	HOUSING STRUCTURES	FARMING AND MINING STRUCTURES	CONSTRUC-TION STRUCTURES	MANUFAC-TURING STRUCTURES	TRANSPOR-TATION & UTILITIES STRUCTURES	RETAIL AND WHOLESALE TRACE STRUCTURES	FINANCE STRUCTURES	SERVICES STRUCTURES	FEDERAL GOVERNMENT STRUCTURES	STATE AND LOCAL STRUCTURES	TOTAL VALUE OF STRUCTURES
Total Estimated Value Exposed in 10^6 1970$	1,106,073	21,026	27,058.1	109,897.4	235,109.4	85,075.9	104,911.4	93,039.0	128,561.01	153,753.8	2,064,507.5
Percent of Total	53.7	1.0	1.3	5.3	11.4	4.1	5.1	4.5	6.2	7.4	100.0
SEVERE WIND											
Exposure Total = 100	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
Est. Loss 10^6 1970$	7.55	.07	.07	.26	.64	.60	.69	.64	.38	.42	11.32
Percent of Total	66.6	0.6	0.6	2.3	5.17	5.3	6.1	5.7	3.4	3.7	100.0
HURRICANE (Wind)											
Exposure Total = 100	32.6	19.2	33.3	28.9	33.5	32.6	39.5	36.5	36.2	31.2	33.1
Est. Loss 10^6 1970$	451.0	3.4	5.3	16.0	45.9	33.6	45.7	37.9	20.9	25.6	685.3
Percent of Total	65.9	0.5	0.8	2.3	6.7	4.9	6.7	5.5	3.0	3.7	100.0
STORM SURGE											
Exposure Total = 100	20.8	13.7	21.1	17.2	24.0	21.5	28.5	24.4	18.0	19.8	21.3
Est. Loss 10^6 1970$	333.	3.1	2.9	7.2	28.9	12.9	15.4	13.2	11.6	13.6	441.8
Percent of Total	75.4	0.7	0.7	1.6	6.5	2.9	3.5	3.0	2.6	3.1	100.0
TORNADO											
Exposure Total = 100	87.2	92.2	88.5	91.2	84.5	87.1	81.1	85.0	87.9	84.9	86.7
Est. Loss 10^6 1970$	502.	7.2	8.8	36.8	75.0	53.9	59.5	53.8	37.6	44.9	879.5
Percent of Total	57.1	0.8	1.0	4.2	8.5	6.1	6.8	6.1	4.3	5.1	100.0
TSUNAMI											
Exposure Total = 100	10.3	3.9	9.7	8.5	11.5	10.6	11.6	11.6	11.1	11.5	10.5
Est. Loss 10^6 1970$	4.52	.004	.02	.04	3.3	.17	.18	.24	.14	.11	8.72
Percent of Total	51.8	0.0	.2	.5		1.9	2.1	2.8	1.6	1.3	100.0
EARTHQUAKE											
Exposure Total = 100	71.9	72.8	71.3	68.5	72.7	71.8	75.1	74.6	75.9	72.7	72.4
Est. Loss 10^6 1970$	354.2	5.7	7.2	24.8	77.9	26.0	34.1	29.1	46.5	49.7	655.2
Percent of Total	54.0	0.9	1.1	3.8	11.9	4.0	5.2	4.4	7.1	7.6	100.0

Table 4-17. Distribution of Building Values and Losses by Type in 1970

POPULATION AT RISK	TOTAL LOSSES (MILLIONS OF DOLLARS)	PER CAPITA LOSS	
		TOTAL	AS % OF PER CAPITA INCOME IN STATE
1. HIGHEST DAMAGE RATE COUNTY*	5.7	219.89	5.82%
2. FIFTH-RANKED COUNTY*	7.2	123.14	3.98%
3. HIGH DAMAGE-RATE STATE (FLA)	749.07	110.32	2.95%
4. FIFTIETH-RANKED COUNTY*	3.2	62.97	1.68%
5. GROUP OF THIRTEEN HIGHEST DAMAGE-RATE STATES	3745.95	58.83	1.48%**
6. TOTAL NATIONAL POPULATION	8081.42	39.76	1.00%**
7. GROUP OF TWENTY-FIVE MEDIUM DAMAGE-RATE STATES	3109.33	35.00	0.88%**
8. MEDIAN DAMAGE-RATE STATE (MICHIGAN)	295.11	33.23	0.80%
9. GROUP OF THIRTEEN LOW DAMAGE-RATE STATES	1226.14	24.17	0.61%**
10. LOW DAMAGE-RATE STATE (WASHINGTON, D.C.)	15.25	20.07	0.40%
11. COUNTRY RANKING 500th IN DAMAGE RATE*	0.62	21.18	0.63%

*Includes only the losses resulting from damage to buildings and does not include losses from riverine flooding. In contrast, data for states includes all losses from all hazards.

**Expressed as percent of national per capita income

Table 4-18. Annual Expected Total and Per Capita Losses for Selected Populations at Risk of Exposure to Nine Natural Hazards, 1970

vary substantially between counties, states, and other identifiable populations at risk.

Expressed as a percentage of per capita income, building losses from all hazards except riverine flooding range from a low of 0.40% in Washington, D.C. to a high of 5.82% in the county exhibiting the nation's highest building damage rate. [See Table 4-18]. If building contents and other losses are considered, these hazard-related demands on per capita income would be approximately thirty percent higher.

At the level of whole states, per capita losses of all types (building, contents, income and supplier losses) range from $16.86 (Vermont) to $110.32 (Florida) and per capita losses as a percentage of per capita income range from $0.40 (D.C.) to $2.95 (Florida).

STATE	BUILDING DAMAGE RATE	RATIO TO NAT'L AVERAGE	RANK	EXPECTED PER CAPITA LOSS '70	RANK	RATIO TO NAT'L AVERAGE	PER CAPITA INCOME	PER CAPITA LOSS AS % OF PER CAPITA INCOME	RANK
FL	.825	2.96	1	110.32	1	2.77	3741	2.95	1
LA	.721	2.59	2	86.07	2	2.16	3097	2.78	2
MS	.477	1.71	3	44.94	13	1.13	2630	1.71	3
KS	.423	1.52	4	57.74	3	1.45	3857	1.50	4
WA	.404	1.45	5	52.43	5	1.32	4053	1.29	9
TX	.398	1.43	6	51.20	7	1.29	3600	1.42	7
MO	.396	1.42	7	55.08	4	1.39	3775	1.46	6
NE	.391	1.40	8	49.82	8	1.25	3786	1.32	8
CA	.375	1.35	9	52.08	6	1.31	4496	1.16	11
OK	.338	1.21	10	49.62	9	1.25	3381	1.47	5
CO	.319	1.15	11	41.87	14	1.05	3851	1.09	14
SD	.311	1.12	12	34.15	21	.86	3101	1.10	13
SC	.311	1.12	13	33.92	22	.85	2992	1.13	12
NC	.310	1.11	14	35.50	18	.89	3256	1.09	15
AL	.309	1.11	15	35.31	19	.89	2947	1.20	10
AR	.299	1.07	16	29.33	28	.74	2886	1.02	20
IA	.291	1.04	17	38.49	16	.97	3755	1.03	19
UT	.286	1.03	18	34.18	20	.86	3218	1.06	17
RI	.284	1.02	19	40.12	15	1.01	3960	1.01	21
CT	.284	1.02	20	48.98	10	1.23	4923	.99	23
ND	.277	.99	21	29.87	27	.75	3191	.94	24
IL	.274	.98	22	48.79	11	1.23	4504	1.08	16
MA	.272	.98	23	45.96	12	1.16	4347	1.06	18
IN	.252	.90	24	37.92	17	.95	3768	1.01	22
ME	.233	.84	25	27.70	35	.70	3309	.84	28
MI	.230	.83	26	33.23	23	.84	4175	.80	30
GA	.223	.80	27	28.83	32	.73	3357	.86	26
VA	.220	.79	28	32.63	25	.82	3720	.88	25
NH	.220	.79	29	33.05	24	.83	3850	.86	27
MN	.215	.77	30	31.55	26	.79	3839	.82	29
WI	.213	.76	31	28.97	31	.73	3809	.76	31
TN	.210	.75	32	22.86	38	.57	3124	.73	32
MT	.202	.73	33	22.20	41	.56	3504	.63	36
WY	.200	.72	34	22.55	39	.57	3816	.59	42
OH	.194	.70	35	28.43	33	.71	4011	.71	33
KY	.192	.69	36	21.15	44	.53	3118	.68	35
DE	.184	.66	37	27.93	34	.70	4527	.62	39
NM	.182	.65	38	21.43	43	.54	3092	.69	34
ID	.179	.64	39	20.13	45	.51	3294	.61	41
WV	.166	.60	40	17.60	49	.44	3070	.57	43
NY	.166	.59	41	29.17	30	.73	4712	.62	40
AK	.164	.59	42	29.19	29	.73	4632	.63	37
NJ	.159	.57	43	27.05	37	.68	4705	.57	44
MD	.155	.56	44	27.23	36	.68	4318	.63	38
NV	.153	.55	45	22.27	40	.56	4563	.49	47
OR	.151	.54	46	18.56	48	.47	3717	.50	46
VT	.137	.49	47	16.86	51	.42	3328	.51	45
PA	.136	.49	48	18.73	47	.47	3970	.47	48
AZ	.130	.47	49	17.30	50	.44	3665	.47	49
HI	.114	.41	50	21.44	42	.54	4623	.46	50
DC	.087	.31	51	20.07	46	.50	5036	.40	51
U.S.	.279			39.76			3966	1.00	

Table 4-19. Per Capita Natural Hazard Expected Losses (Building, Contents, Income and Supplier Cost) for Nine Study Hazards, by State, 1970

At a finer scale, the 500 most damage-prone counties of the United States exhibited building damage rates that varied from 0.287% to 3.51% of building value [See Table 4-20] and per capita losses that ranged from $21.18 to $219.89 [See Table 4-18]. When these building losses are expressed as a percent of per capita income, they varied from 0.63% to 5.82% of per capita income.

HAZARD TYPES	EXPECTED ANNUAL BUILDING LOSS FOR COUNTY OF INDICATED RANK*				
	RANK 1	RANK 10	RANK 50	RANK 100	RANK 500
1. EARTHQUAKE, TSUNAMI, STORM SURGE, TORNADO, AND HURRICANE WIND	3.43%	1.40%	0.743%	0.405%	0.14%
2. EXPANSIVE SOIL, LANDSLIDE, AND SEVERE WIND	0.462%	0.262%	0.260%	0.234%	0.113%
3 ALL HAZARDS, EXCEPT RIVERINE FLOODING	3.51%	1.444%	0.784%	0.483%	0.287%

* Represents 500 most damage-prone counties of U.S., ranked in descending order by damage rate (e.g. proportion of building value expected to be lost, annually for indicated hazard category)

Table 4-20. Proportion of Building Value Expected to be Lost, Annually, in Several "Most Damage Prone" Counties of U.S. as Result of Exposure to Selected Natural Hazards, 1970

In terms of the several states of the Union, the aggregate of damage rates induced by all nine hazards ranged from 0.087% to 0.825%; annual expected total per capita losses varied from $16.86 to $110.32; and total per capita losses as a percent of per capita income ranged from 0.40% to 2.95% [See Table 4-19]. State-level losses (total and per capita) as a function of the damage-rate class of states, are depicted in Table 4-21.

The steep gradient in losses experienced by the several population at risk of exposure to each hazard is depicted by the data presented in Table 4-22.

Estimates of natural hazard losses and other effects also were developed for the year 2000. These estimates were based on projected increases in building and human populations in the several hazard exposure areas (counties, states and flood-

HAZARD	TOTAL LOSS BY BUILDING DAMAGE RATE CLASS, 1970 (MILLIONS OF DOLLARS)				PER CAPITA LOSS BY DAMAGE RATE CLASS, 1970 DOLLARS			
	(1) NBDR* x 2	(2) NBDR x 1 AND GREATER	(3) 0.5 TO 0.99 x NBDR	(4) 0.0 TO .49 x NBDR	(1) NBDR x 2	(2) NBDR x 1 AND GREATER	(3) 0.5 TO 0.99 x NBDR	(4) 0.0 TO .49 x NBDR
FLOOD	--	1746.9	1011.5	--	--	15.41	11.25	--
STORM SURGE	431.2	549.5	83.6	8.6	31.71	13.05	2.25	.07
TSUNAMI	14.2	14.2	--	--	.58	.58	--	--
TORNADO	818.6	1279.6	233.4	138.2	21.26	14.54	6.28	1.77
HURRICANE	626.4	911.1	118.1	27.4	23.28	15.70	4.31	.23
SEVERE WIND	2.9	8.4	4.0	--	.12	.11	.05	--
EARTHQUAKE	689.1	728.7	7.0	43.0	25.61	20.24	2.11	.26
LANDSLIDE	--	238.7	124.4	7.2	--	2.29	1.46	.53
EXPANSIVE SOIL	467.9	612.2	57.5	128.4	9.82	7.52	2.35	1.32
ALL HAZARDS	1062.36	4435.74	3354.84	290.8	101.86	54.11	31.73	18.72

*(NBDR) - National Building Damage Rate

Table 4-21. Total and Per-Capita Economic Losses Induced by Natural Hazard Exposures by Type and Building Damage Rate Class, 1970

control regions) and generally assumed no change in land-use zoning, building codes, and new construction practices. This element in the loss analysis revealed that annual expected losses will jump to $17,774.85 million in the year 2000; that hazard-related deaths will climb to 1,790 per year; and that other annual expected adverse events will record a similar sharp increase [See Table 4-2].

By the year 2000, the annual expected per capita loss from natural hazard exposures will nearly double. The hazards of principal importance to this doubling of per capita losses are tornado, hurricane, riverine flooding, storm surge, and earthquake [See Tables 4-23, 4-24].

POPULATION AT RISK OF EXPOSURE TO INDICATED HAZARD	1970 POPULATION (MILLIONS OF PERSONS)	1970 ANNUAL EXPECTED LOSS (MILLIONS OF DOLLARS)	1970 ANNUAL EXPECTED PER CAPITA LOSS ($)
1. SEVERE WIND:			
A. STATE WITH HIGHEST ANNUAL EXPECTED DAMAGE RATE FOR HAZARD (WYOMING)	0.33	0.1	0.30
B. NATIONAL POPULATION OF ALL COUNTIES AT RISK OF EXPOSURE TO HAZARD	203.23	11.4	0.06
C. NATIONAL POPULATION OF STATES WITH BUILDING RATES (BDR) EQUAL TO OR GREATER THAN 2 x THE NATIONAL BUILDING DAMAGE RATE (NBDR)	23.29	3.4	0.15
D. NATIONAL POPULATION OF ALL STATES WITH BDR ≧ 1 x NBDR	73.92	7.7	0.10
2. TORNADO			
A. THREE COUNTIES WITH HIGHEST BDR - AND OVER 100 TORNADO STRIKES ANNUALLY (OKLAHOMA)	.066	1.58	23.97
B. STATE WITH HIGHEST ANNUAL EXPECTED DAMAGE RATE FOR HAZARD (OKLAHOMA)	2.56	43.5	16.99
C. NATIONAL POPULATION OF ALL COUNTIES AT RISK OF EXPOSURE TO HAZARD	181.199	879.8	4.86
D. NATIONAL POPULATION OF STATES WITH BUILDING DAMAGE RATES (BDR) EQUAL TO OR GREATER THAN 2 x THE NATIONAL BUILDING DAMAGE RATE (NBDR)	38.5	435.8	11.32
E. NATIONAL POPULATION OF ALL STATES WITH BDR ≧ 1 x NBDR	88.01	681.2	7.74
F. NATIONAL POPULATION OF ALL STATES WITH BDR LESS THAN 0.50 NBDR	78.07	76.5	0.98
3. EXPANSIVE SOILS:			
A. INTRA-COUNTY POPULATIONS IN HIGH HAZARD ZONES	17.73	--	26.00
B. INTRA-COUNTRY POPULATIONS IN MODERATE HAZARD ZONES	23.71	--	8.00
C. INTRA-COUNTY POPULATIONS IN LOW HAZARD ZONES	98.32	--	1.50
4. EARTHQUAKE			
A. STATE WITH HIGHEST ANNUAL EXPECTED DAMAGE RATE FOR HAZARD (WASHINGTON)	3.41	96.9	28.42
B. NATIONAL POPULATION OF STATES WITH BDR ≧ 2 x NBDR	26.91	572.5	21.27
C. NATIONAL POPULATION OF ALL COUNTIES AT RISK OF EXPOSURE TO HAZARD	143.169	655.2	4.58
D. NATIONAL POPULATION OF STATES WITH BDR LESS THAN 0.5 x NBDR	163.92	43.4	0.26
5. HURRICANE:			
A. STATE WITH HIGHEST ANNUAL EXPECTED DAMAGE RATE FOR HAZARD (FLORIDA)	6.79	190.4	28.04
B. NATIONAL POPULATION OF STATES WITH BDR ≧ 2 x NBDR	26.91	401.6	14.92
C. NATIONAL POPULATION OF ALL COUNTIES AT RISK OF EXPOSURE TO HAZARD	62.741	685.4	10.92
D. NATIONAL POPULATION OF STATES WITH BDR LESS THAN 0.5 x NBDR	117.76	17.8	0.15
6. LANDSLIDES			
A. NATIONAL POPULATION OF ALL COUNTIES IN HIGH RISK LANDSLIDE AREAS	44.07	--	4.25
B. NATIONAL POPULATION IN MEDIUM RISK AREAS	39.43	--	0.80
C. STATE WITH HIGHEST ANNUAL EXPECTED DAMAGE RATE FOR HAZARD (WEST VIRGINIA)	1.74	4.88	2.80
D. STATE WITH HIGHEST PER CAPITA LOSS (CONNECTICUT)	3.03	10.30	3.40
E. NATIONAL POPULATION OF STATES WITH BDR ≧ 1 x NBDR	104.53	23.87	2.29
F. NATIONAL POPULATION OF STATES WITH BDR LESS THAN 0.5 x NBDR	13.46	7.2	.53
7. STORM SURGE:			
A. SURGE-PRONE AREAS OF GEORGIA	0.036	4.355	121.37
B. SURGE-PRONE AREAS OF FLORIDA	2.468	195.271	79.14
C. SURGE-PRONE AREAS OF GULF COAST (NOT INCLUDING FLORIDA)	2.269	117.708	51.88
D. SURGE-PRONE AREAS OF SOUTH ATLANTA (VIRGINIA, NORTH CAROLINA, SOUTH CAROLINA, GEORGIA)	1.520	32.624	21.46
E. SURGE-PRONE AREAS OF MIDDLE AND NORTH ATLANTIC	3.683	95.988	26.06
F. ALL SURGE-PRONE AREAS OF UNITED STATES	9.940	441.591	44.43
G. SURGE-PRONE AREAS OF NEW HAMPSHIRE	0.011	0.032	2.98
8. RIVERINE FLOODING			
A. FLOOD ZONES A-C IN COMMUNITIES NOT PROTECTED FROM FIFTY-YEAR FLOODS	2.895	1,164.09	402.16
B. FLOOD ZONES A-C IN COMMUNITY PROTECTED FROM FIFTY-YEAR FLOODS	3.091	247.09	79.94
C. FLOOD ZONE E (50-100 YR. T.P.) IN ALL FLOOD PRONE COMMUNITIES	3.332	111.8	33.55
D. FLOOD ZONES A-E, ALL FLOOD-PRONE COMMUNITIES	12.341	1,710.4	138.59
E. FLOOD ZONES A-F, ALL FLOOD PRONE COMMUNITIES	24.683	1,901	77.02
9. TSUNAMI			
A. 500 YEAR TSUNAMI	.23	8.7	36.63
B. STATE WITH HIGHEST EXPECTED DAMAGE RATE (HAWAII)	.77	4.1	5.32
C. COUNTIES IN WHICH INUNDATION AREAS ARE LOCATED	18.201	8.7	0.47

Table 4-22. Expected Annual Per Capita Building Damage Loss from Natural Hazards for Selected Populations-at Risk, 1970

HAZARD	TOTAL LOSS BY BUILDING DAMAGE RATE CLASS, 2000 (MILLIONS OF DOLLARS)				PER CAPITA LOSS BY DAMAGE RATE CLASS, 1970 DOLLARS			
	(1) NBDR* x 2	(2) NBDR x 1 AND GREATER	(3) 0.5 TO 0.99 x NBDR	(4) 0.0 TO .49 x NBDR	(1) NBDR x 2	(2) NBDR x 1 AND GREATER	(3) 0.5 TO 0.99 x NBDR	(4) 0.0 TO .49 x NBDR
FLOOD	--	1819.1	1355.8	--	--	15.31	9.87	--
STORM SURGE	1692.2	1772.3	524.9	45.7	88.97	67.46	7.38	.29
TSUNAMI	40.5	40.5	--	.1	1.29	1.29	--	--
TORNADO	2463.7	4033.1	752.6	433.3	54.12	36.58	15.88	4.40
HURRICANE	2274.2	3073.3	335.7	117.0	61.90	40.72	11.06	.78
SEVERE WIND	12.1	31.7	14.4	2.5	.52	.36	.14	.04
EARTHQUAKE	1359.6	1451.1	14.2	86.5	39.28	31.62	3.89	.42
LANDSLIDE	--	551.0	298.2	22.1	--	4.37	2.73	1.07
EXPANSIVE SOIL	583.4	756.3	113.3	127.5	9.87	7.59	2.32	1.19
ALL HAZARDS	3809.9	11885.5	5232.3	657.0	245.48	100.76	46.82	24.91

*(NBDR) - National Building Damage Rate

Table 4-23. Total and Per-Capita Economic Losses Induced by Natural Hazard Exposures by Type and Building Damage Rate Class, 2000

HAZARD	EXPECTED ANNUAL PER CAPITA LOSS FOR INDICATED YEAR	
	1970	2000
1. RIVERINE FLOODING	$13.57	$12.40
2. TORNADO	8.12	20.38
3. HURRICANE	5.20	13.77
4. EXPANSIVE SOIL	3.93	3.89
5. EARTHQUAKE	3.83	6.07
6. STORM SURGE	3.16	9.15
7. LANDSLIDE	1.82	3.40
8. TSUNAMI	.07	.16
9. SEVERE WIND	.06	.19
ALL HAZARDS	$39.76	$69.41

Table 4-24. Expected Annual National Per Capita Dollar Losses from Natural Hazard Exposures in the United States, by Type of Hazard, 1970 and 2000

Projected Increase in Natural Hazard Losses

Between 1970 and 2000, annual expected dollar losses from natural hazard exposures will increase by approximately 9.7 billion dollars, an amount which is 19.7% greater than all annual expected losses in 1970, [See Table 4-25].

HAZARD	EXPECTED ANNUAL DOLLAR LOSS* (MILLIONS)			PERCENT OF INCREASE
	1970	2000	INCREASE	
1. WATER HAZARDS:	3,414.5	5,558.6	2,144.1	63
RIVERINE FLOODING	2,758.3	3,175.3	417.0	15
STORM SURGE	641.2	2,342.9	1,701.7	265
TSUNAMI	15.0	40.4	25.4	169
2. WIND HAZARDS:	2,730.0	8,798.8	6,068.8	222
TORNADO	1,656.0	5,219.1	3,563.1	215
HURRICANE	1,056.0	3,526.3	2,470.3	234
OTHER SEVERE WIND	18.0	53.4	35.4	197
3. EXPANSIVE SOIL	798.1	997.1	199.0	25
4. EARTHQUAKE	781.1	1,553.7	772.6	99
5. LANDSLIDE	370.3	871.2	500.9	135
TOTALS	8,094.0	17,779.4	9,685.4	120

*Losses calculated in 1970 dollars and are confined to dollar losses caused by damage to buildings and building contents as well as income and supplier losses related thereto

Table 4-25. Expected Annual U.S. Dollar Losses from Natural Hazard Exposures, 1970 and 2000

The combination of storm surge and hurricane wind losses will total $22.92 in 2000 and will make hurricanes the leading source of national per capita loss in that year, followed closely by tornadoes ($20.38). Because of the expected impacts of area flood control projects and floodplain zoning, per capita losses from riverine flooding in 2000 will drop below 1970 levels and reduce the comparative loss-producing importance of this hazard.

Two factors are of particular importance to the 1970-2000 escalation of total hazard dollar losses: (1) predicted increase in the ratio of building content value to building value, and (2) the predicted large rates of migration of population and investment capital into hazard-prone areas.

As depicted in Table 4-26, the thirteen states which, in 1970, ranked among the upper one-fourth of all states in terms of building damage rates, will experience 31.54% of all the building wealth additions projected for that 30-year period, and will account for 53.07% of the estimated increase in total dollar losses for all natural hazards within that same period.

STATE CATEGORY	NUMBER AND PROPORTION IN CATEGORY		BUILDING WEALTH INCREASE, 1970 - 2000		INCREASE IN TOTAL DOLLAR LOSSES, ALL HAZARDS, 1970 - 2000	
	N	%	N	%	N	%
HIGH DAMAGE RATE STATES	13	25.5%	902.3	31.54%	5140.03	50.71%
MEDIUM DAMAGE RATE STATES	25	49.0%	1195.4	41.79%	3295.98	35.07%
LOW DAMAGE RATE STATES	13	25.5%	763.0	26.67%	1249.42	14.22%
TOTALS	51	100.0%	2860.7	100.00%	9685.43	100.00%

Table 4-26. Relationship Between State Damage Rates, Projected Increases in Building Wealth, and Estimated Increases in Natural Hazard Losses, 1970-2000

Although a lower than expected proportion of high damage rate states exhibit high rates of building wealth addition between 1970 and 2000 [See Table 4-27], application of the Chi Square test to the contingency table presented as Table 4-27 reveals that the observed differences in proportion of high and low growth rate states among the several classes of damage rate states lacks statistical significance and could be due to chance alone.

Based on available data, therefore, it appears that the hazard proneness of states does not influence rates of migration to, and capital investment within, those states. The higher hazard rating of some states does not seem to deter their growth of population and building value. Indeed, it is the large thirty-year projected increase in building wealth additions in high damage rate states, and counties, principally along the Gulf Coast and South Atlantic, that accounts for much of the projected increase in annual expected natural hazard losses between 1970 and 2000. Thus, the proportion of the total national value of buildings and building contents in low damage rate states will decline between 1970 and 2000 while the proportion in high damage rate states will increase [See Table 4-28].

CLASSIFICATION BY STATE BUILDING DAMAGE RATE	NUMBER AND PROPORTION OF STATES WITH INDICATED PROJECTED RATE OF GROWTH IN BUILDING VALUE 1970 - 2000						TOTAL	
	HIGH GROWTH RATE (151.7 - 225.4%)		MEDIUM GROWTH RATE (119.4 - 147.1)		LOW GROWTH RATE (85.4 - 119.1)			
	N	%	N	%	N	%	N	%
HIGH DAMAGE RATE STATES (DR 0.0316 - 0.0829)	2	15.4%	6	46.2%	5	38.5%	13	100.0%
MEDIUM DAMAGE RATE STATES (DR 0.0196 - 0.0308	5	20.0%	14	56.0%	6	24.0%	25	100.0%
LOW DAMAGE RATE STATES (DR 0.0114 - 0.0195)	6	46.2%	5	38.5%	2	15.4%	13	100.0%
TOTALS	13	-	25	-	13	-	51	-

Table 4-27. Relationship Between State Damage Rates and Projected Increases in Building Wealth, 1970-2000

STATE CATEGORY	NUMBER AND PROPORTION IN CATEGORY		VALUE OF BUILDINGS AND BUILDING CONTENTS			
			1970		2000	
	N	%	N	%	N	%
HIGH DAMAGE RATE STATES	13	25.5	3643.40	47.52	8297.36	49.64
MEDIUM DAMAGE RATE STATES	25	49.0	2802.22	36.55	5915.86	35.39
LOW DAMAGE RATE STATES	13	25.5	1220.98	15.93	2501.62	14.97
TOTALS	51	100.00%	7666.60	100.00%	16714.85	100.00%

Table 4-28. Value of Buildings and Building Contents Exposed to Natural Hazards, Classified by Damage Classification of Three Groups of Counties, 1970 and 2000

Referent Effects and Problems

The possible significance of projected natural hazard losses may be examined by comparing these losses with other social costs which typically are viewed as constituting contemporary problems within U.S. society.

One suggested set of comparisons is presented in Table 4-29. As shown there, the 30-year total annual expected increase in natural hazard losses is, alone, greater than the sum of the 1970 aggregated costs represented by all crimes against property, all annual investments in water pollution control facilities, all business losses due to six major types of criminal activities, and all building losses due to fire. Similarly, that increase approaches the value of all health insurance premium payments in 1970 and is greater than such other costs as those resulting from auto liability insurance premiums, accidents at work, losses from air pollution-morbidity and mortality, air pollution effects on the value of property, and all expenditures by state and local police departments. The total annual expected loss from natural hazard exposures in 2000 is greater than the total 1970 economic effects of air pollution; greater than the losses caused by all traffic accidents in 1970; and is equal to 52.2% of all 1970 property tax collections by all state and local governments.

The annual expected losses from natural hazards in 1970 were nearly equal to the total sums expended by owner/occupants of one-unit properties in the United States for the improvement, maintenance, and repair of their dwelling units.[1] In the group of thirteen highest damage rates states, in 1970, total annual expected household losses from natural hazards equalled $195.95 as compared to the national average owner/occupant expenditures of $265 for the maintenance and repair of one-unit housing structures.[2]

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[1] See Table 4-1, this chapter, and the Statistical Abstract of the United States 1975, Table 1209.

[2] Household estimates of natural hazard losses assume 3.2 persons per household [See Statistical Abstract of the United States, 1975, Table 49] and the annual per capita hazard losses described earlier. 1970 expenditures for dwelling unit improvements, maintenance, and report totalled $9,469 million or an average of about $265 per household [See Statistical Abstract of the United States, 1975, Table 1209, p. 709.]

TYPE OF LOSS OR EVENT	VALUE IN 1970 (MILLIONS OF $)
1. ALL PROPERTY TAX COLLECTIONS BY STATE AND LOCAL GOVERNMENTS	34,054
2. ALL ACCIDENTS	27,000
3. ALL TRAFFIC ACCIDENTS	16,200
4. TOTAL ECONOMIC EFFECTS OF AIR POLLUTION	16,000
5. HEALTH INSURANCE PREMIUMS	11,546
6. INCREASE IN ANNUAL EXPECTED LOSSES FROM NATURAL HAZARDS, 1970-2000	9,685
7. POLLUTION CONTROL COSTS (AIR, WATER, SOLID WASTES)	9,300
8. AUTO LIABILITY INSURANCE PREMIUMS	8,958
9. EXPECTED ANNUAL NATURAL HAZARD LOSSES	8,094
10. LOSSES FROM ACCIDENTS AT WORK	8,000
11. LOSSES FROM AIR POLLUTION-RELATED MORBIDITY AND MORTALITY	6,000
12. AIR POLLUTION EFFECTS ON VALUE OF PROPERTY	5,200
13. AIR POLLUTION EFFECTS ON MATERIALS AND VEGETATION	4,900
14. EXPENDITURES BY ALL STATE AND LOCAL POLICE DEPARTMENTS	4,494
15. ALL CRIMES AGAINST PROPERTY	4,264
16. INVESTMENTS IN WATER POLLUTION CONTROL FACILITIES	3,100
17. BUSINESS LOSSES DUE TO SIX TYPES OF CRIMINAL ACTIVITIES	3,049
18. BUILDING LOSSES DUE TO FIRES	2,209

Sources:

1. The Statistical Abstract of the U.S., Bureau of the Census, Dept. of Commerce, Grosset & Dunlap Publishers, New York 1976. p. 258.
2. Accident Facts, National Safety Council, Chicago, Illinois, Prepared by the Statistics Division, 1971. p. 4.
3. Insurance Facts 1971, Insurance Information Institute, New York. p. 51.
4. Environmental Quality, the Second Annual Report of the Council on Environmental Quality U.S. Government Printing Office, Washington D.C. August 1971, p. 107.
5. The Statistical Abstract of the U.S., p. 484.
7. Environmental Quality, 1971, p. 112.
8. The Statistical Abstract of the U.S., p. 485
10. Insurance Facts 1971, p. 59.
11. Environmental Quality, 1971, p. 106.
12. Environmental Quality, 1971, p. 107.
13. Ibid.
14. The Statistical Abstract of the U.S., p. 258.
15. Insurance Facts 1971, p. 61.
16. Environmental Quality, 1971, p. 112.
17. The Statistical Abstract of the U.S., p. 159.
18. The Statistical Abstract of the U.S., p. 486.

Table 4-29. Annual Expected Losses from Nine Natural Hazards in 1970, Compared with Annual Value of Other Types of Losses and Events

Similarly, the loss analysis revealed that 113,884 housing units could be expected to be lost from exposure to natural hazards in 1970. This number of housing units is equal to 7.75% of all the new housing units placed on stream in the United States in that year.[1]

Still another referent useful in judging the real impacts of natural hazard losses is the following comparison of annual natural hazard losses per household as contrasted to the annual costs or savings involved in a 1% shift in the interest rates for home mortgages. As shown in Table 4-30, a 1% shift in the interest demand for a $25,000, 25-year home mortgage produces a change in an annual household cost of $202.08. In contrast, 1970 annual expected household costs for natural hazard losses in three member households totalled $119.28. The ratio of annual interest rate costs (assuming a 1% upward movement in interest rates) to annual natural hazard losses varies from 1.69:1 to 3.05:1, depending on the size of the mortgage.

SIZE OF MORTGAGE	ANNUAL PAYMENT AT		ANNUAL DIFFERENCE IN INTEREST RATE	ANNUAL HAZARD COSTS	RATIO OF INCREASED ANNUAL INTEREST RATE COSTS TO NATURAL HAZARD LOSSES
	8%	9%			
$25,000	2315.52	2517.6	202.08	119.28	1.69:1
$30,000	2778.6	3021.12	242.52	119.28	2.03:1
$35,000	3241.68	3524.64	282.96	119.28	2.37:1
$40,000	3704.75	4028.16	323.41	119.28	2.71:1
$45,000	4167.68	4531.68	363.84	119.28	3.05:1

Table 4-30. Annual Expected Hazard Losses Per Household as Compared with Household Annual Costs Associated with a One-Percent Shift in Mortgage Interest Rates

Natural hazard losses also may be compared with the losses resulting from fires and from expenditures for fire abatement services. According to the National Household Fire Survey,[2] annual national fire losses for single detached structures, garages, sheds, apartments, and vacation homes total approximately $1,213 million annually. In 1974, all state and local expenditures for fire protection payrolls totalled $2,700 millions[3]. Thus, in 1970 natural hazard losses ($8,258.7 million)

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[1] Statistical Abstract of the United States 1975, (Table 1212, p.711).

[2] U.S. Department of Commerce, National Fire Prevention and Control Administration, Highlights of the National Household Fire Survey, 1976, p. 14.

[3] Derived from Statistical Abstract of the United States, 1975, Table 440, p. 272. The annual total is the October payroll for 1974 multiplied by 12.

in the United States are substantially in excess of the sum of comparatively recent annual losses from fires to structures and the cost of support of all state and local fire abatement and fire prevention personnel.

However, since there are approximately 2.4 million loss-producing fires annually, the threat of fires to structures may be viewed as comparatively high probability events, as compared with most natural hazards. Since such events seem to produce more acute responses from the general public then do low-probability events, in spite of the possible higher long-term accumulated losses arising from the later, there is substantially less than full certainty that the general public will respond to natural hazard losses with the same vigor that they have entered into payment of fire insurance premiums and into support of local fire prevention and abatement services.

Nonetheless, the sum of the referent information presented above suggests that natural hazard losses, both in the aggregate and in terms of their per capita and per household values, are of a magnitude approximating other expenditures or losses which generally are viewed as being extremely important in our society.

Conclusions

The data derived from the loss analysis seem to support six major problem-focused conclusions:

1. Natural hazard dollar losses are of a magnitude equal to or approaching the costs of other phenomena which generally are viewed as problems in our society

   The nine natural hazards examined in this study produced annual expected dollar losses totalling $8,094.0 million in 1970 and are expected to produce annual losses totalling $17,779.43 in the year 2000. Representing economic losses sustained by wage earners, suppliers, and the owners of buildings and building contents, these losses exceed the 1970 value of such generally disvalued phenomena as all building losses due to fires, all crimes against property, all expenditures by state and local police departments, and the value of all losses resulting from accidents at work. The thirty-year expected increase in annual expected natural hazard losses ($9685 million) approaches the 1970 value of all annual premium payments for health insurance policies. For the nation as a whole, the nine natural hazards considered in this analysis produce annual expected per capita losses of $39.76 in 1970 and will produce expected annual per capita losses of approximately $69.41 in the year 2000. In both years, four of the nine natural hazards account for 77.52% to 72.67% of these losses: riverine flooding, tornado, expansive soil, and hurricane.

2. <u>Risk takers and their related communities-at-interest currently experience much unevenness in the actual natural hazard losses which they sustain each year</u>

Many of the hazards examined in this study, and for which annual expected damage losses were calculated, may be viewed as comparatively low probability-high consequence occurrences. Thus, hurricane, earthquake, storm surge, and tsunami accounted for nearly 31% of the annual expected national per capita hazard losses for 1970. In any particular heavily populated area, the probability in any year that a major high-intensity event of these types will occur is comparatively small. However, when such events do occur, they are capable of producing losses representing a substantial fraction of the annual income and building value of the impacted area. For example, if a Richter magnitude 8.3 earthquake were to occur in the 39-county San Francisco Bay Area in the year 2000, it could be expected to produce building value losses of $18.155 billion and a total dollar loss of $39.9 billion. Such a loss would be more than double the national, annual, all-hazard expected losses for the same year. Sudden, large magnitude dollar losses of this type may severely impair the recovery capacity of a community, state, or region because of the large short-term demand they make upon available capital and annual incomes. If actuarily sound financial reserves were developed to finance recovery from low probability-high consequence events, then the problems produced by unevenness in annual economic losses could be corrected. In the absence of such systems, however, the uneven temporal distribution of losses must itself be viewed as a potential problem of considerable magnitude.

3. <u>Substantial unevenness in the distribution of annual per capita loss burdens is exhibited by the several hazard-specific and geographically-identifiable risk-taker and community-at-interest groups identified in the study</u>

On a total national basis, the annual expected per capita losses resulting from natural hazard exposures in 1970 and 2000 are not particularly large. For example, the 1970 annual expected per capita loss is $39.76 and is equal to only 1.00% of per capita national income in that year. Assuming 3.2 persons per household, average national household burdens are $127 and $222 for 1970 and 2000, respectively. Such annual losses per household do not appear to be very burdensome, as compared with other major household expenditures.

However, per capita losses vary widely among the several populations exposed to hazards or exposed to the risk of bearing hazard-induced community costs. For example, if all 1970 riverine flood losses are distributed among the members of the population which actually reside in U.S. riverine floodplains, this loss burden would produce an annual expected per capita loss of $114.40 per floodplain resident, or an annual expected household loss of $366.08. Similarly, several million persons in the United States reside in intra-county areas in which they are exposed to a high level of expansive soil hazard and where they will experience annual per capita losses from this hazard totalling $26.00. The nearly 27 million people residing in states exposed to a high level of earthquake hazard are at risk of experiencing an annual per capita loss of $21.27 from this hazard exposure. Residents in the State of Florida, where a comparatively high frequency of hurricane episodes can be expected, were at risk of experiencing 1970 annual expected per capita losses, totalling $28.04 for hurricanes and $28.72 for storm surge. In contrast, the 90 million persons residing in states with the lowest riverine flood losses were expected to experience an annual per capita loss of only $7.76 for this hazard in 1970. In terms of the several States of the Union, total annual expected losses for all hazards varied from a low of $16.86 in Vermont to a high of $110.32 in Florida.

When this unevenness in annual expected hazard losses between the several populations at risk is combined with the year-by-year unevenness in actual loss experience, it is clear that personally catastrophic losses from natural hazards may be experienced by numerically significant population subsets in the United States in any given year.

4. Improvident patterns of interstate migration and capital investment are the major causes of the large projected increase in natural hazards between 1970 and the year 2000.

The thirteen states which exhibited the highest 1970 building damage rate for exposure of property to natural hazards will account for nearly 32% of the projected increase in building wealth between 1970 and 2000. In contrast, the thirteen states with the lowest building damage rates will account for only 27% of the projected building wealth increase for the same period. When combined with the higher probability that the population, buildings and other wealth drawn to those states will be at higher risk of exposure to more frequent and higher magnitude hazards, the higher rates of growth in the high damage rate states result in a situation where the high damage rate states of the Union will account for nearly 51% of the increase in annual expected hazard-induced dollar losses which will occur between the year 1970 and 2000.

These improvident interstate patterns of migration unquestionably are matched by equally improvident intra-state and intra-county patterns of community development which further exacerbate the economic and other effects of natural hazard occurrences. Continued development of such hazardous areas as those characterized by high soil expansivity, by their location in or proximity to 50-and 100-year floodplains, and by their proximity to areas in which hurricane wind, storm surge, and tsunami damages will be experienced simply exacerbate the magnitude of projected hazard-induced dollar and other losses. Large as 1970 annual expected hazard losses may have been, they are dwarfed by the thirty-year increase which is expected to occur between 1970 and 2000. Almost the entirety of that projected increase is unnecessary and avoidable in the sense that hazard-avoidance strategies would, alone, substantially reduce - if not eliminate - those increases.

5. Annual expected per capita losses from natural hazards generally are insufficiently high to provide incentives for individuals to make appropriate hazard-avoiding or hazard-mitigating decisions

In spite of the large estimated aggregated annual losses from natural hazard exposure, and in spite of the fact that some populations at risk may experience burdensome annual per capita losses from such exposures, these per capita burdens generally are insufficiently high to stimulate migrants and investors in property to avoid high hazard areas. The natural, climatologic, and other amenities associated with migrant receptor areas apparently outweigh - in the minds of migrant and invest risk takers - the burdens associated with high hazard exposures in those areas. Although low probability-high consequence events may be most disvalued by loss-experiencers at the time of their occurrence, these same classes of events apparently do not motivate potential risk takers to retreat from situations in which those events may occur. Instead, the largest fraction of the U.S. population apparently draws its motivations from its knowledge of comparatively short-term cycles of events. Thus, such comparatively high probability but low consequence events as structural fires act as more powerful motivators for personal use or risk mitigating strategies than do such low probability-high consequence events as earthquakes and tsunamis.

6. As compared with other significant phenomena, natural hazard exposures do not produce high annual expected losses of lives, jobs and homes:

For 1970, the study revealed that 784 deaths per year could be expected from the exposure of populations to earthquakes, hurricanes, storm surge, tornado and tsunami hazards. For the year 2000, the study revealed that 1620 deaths could be expected each year from population exposures to the same hazards. Even if these annual expected mortality levels were doubled or tripled in order to take account of potential life-loss from riverine flooding, the resulting numbers of death per year are not impressive as compared with other causes of death within the United

States. Thus, for the 15-to-24-year age segment of the U.S. population, alone, annual deaths from all accidents total approximately 27,175. Suicide within this same age group results in nearly 4200 deaths per year.* In 1970, motor vehicle accidents caused nearly 55,000 deaths among the total U.S. population and all other accidents were responsible for approximately 60,000 deaths. Suicide produced 23,500 deaths while homocides produced another 16,800. Diseases of early infancy were responsible for 43,200 deaths in the same year, while cirrhosis of the liver was responsible for 31,400 deaths.

If a large dollar investment is necessary to substantially reduce expected life loss from natural hazard exposures, then it is more than conceivable that a diversion of those funds into other public life-saving strategies would secure even greater annual reductions in life loss. Thus, measured by number of human lives saved per year, there may be substantial "opportunity costs" associated with investment of national resources in hazard-mitigating policies in order to reduce expected life loss from population exposures to natural hazards.

*Calculated from data presented in Tables 35 and 86, Statistical Abstract of the United States, 1975.

Chapter Five

COSTS AND IMPACTS OF NATURAL HAZARD MITIGATION TECHNOLOGIES

Introduction and Summary

Projected annual expected losses from natural hazard exposures may be reduced through prudent use of avoidance, area structural protection, building strengthening, site preparation, and building removal strategies. Building damage losses, alone, may be reduced from projected 2000 values by approximately 41.6 percent through use of selected technologies in these several classes. However, the widespread application of technologies in these several classes will produce direct and indirect costs of considerable magnitude, as well as primary, secondary, and higher-order impacts on American society. This chapter examines the loss reductions which are possible through use of selected hazard-mitigating technologies, the costs associated with use of such technologies, and the implications of these findings to natural hazard management programs.

Summary of Loss Estimates for Nine Natural Hazards

The loss reduction analysis resulted in the generation of six sets of annual expected building damage loss estimates, each of which is presented in Table 5-1.

HAZARD	1970 ANNUAL EXPECTED LOSS (MILLIONS $)	ANNUAL EXPECTED LOSSES IN 2000 (MILLIONS OF 1970$)				
		LEVEL #1 (NO MITIGATIONS)	LEVEL #2 (EXPECTED LOSSES)	LEVEL #3 (LOSSES UNDER "MOST EFFECTIVE" MITIGATION)	LEVEL #4 (LOSSES UNDER "MOST EFFECTIVE" COST FEASIBLE MITIGATION)	LEVEL #5 (LOSSES UNDER HIGHEST "NET SAVINGS" MITIGATION)
	A	B	C	D	E	F
1. EARTHQUAKE	655.2	1378.5	1177.0	1084.0	1174.3	1174.3
2. EXPANSIVE SOILS	798.1	997.1	997.1	760.1	969.2	969.2
3. LANDSLIDE	370.3	871.2	871.2	349.4	349.4	349.4
4. HURRICANE	685.5	1742.0	1742.0	1280.0	}	
5. SEVERE WIND	11.4	24.8	24.8	19.1	} 3217.4	3217.4
6. TORNADO	879.8	2058.0	2058.0	1564.0	}	
7. RIVERINE FLOODING	1901.0	2634.0	1594.0	953.4	1653.0	1694.2
8. STORM SURGE	442.0	1176.0	1176.0	334.8	826.2	912.8
9. TSUNAMI	8.7	19.8	19.8	19.4	19.4	19.4
TOTAL	5752.0	10901.4	9659.9	6364.2	8208.9	8336.7

Table 5-1. Annual Expected Natural Hazard Building Damage Losses under Several Alternative Assumptions, 1970 and 2000

The first of these estimates, of course, is for 1970. The remaining five sets of loss estimates are for the year 2000 and represent different sets of assumptions, as follows:

Level One Estimates:

These estimates are intended solely to provide a baseline against which the impact and cost-payoff relationships for selected mitigations may be calculated. For only two hazards, earthquake and riverine flooding, do level #1 and level #2 estimates differ from each other. For these two hazards, level #1 estimates assume that mitigations now being applied to deal with these hazards are suspended in the period 1980 through 2000. In the case of riverine flooding, the estimate assumes that current ongoing levels of construction of area flood protection works will be halted in 1980, and that, beginning in the same year, no further progress will be made to limit building construction in the nation's 50-year riverine flood plains.

Level Two Estimates:

These estimates are intended to represent the level of annual expected losses that will be experienced in 2000 if current population trends, migration patterns, building practices, and zoning policies are continued. In the case of wind resistance standards, the basic assumption is that all areas of the country now are observing UBC standards. Since many local areas may not, in fact, be conforming to such standards, these loss estimates probably are somewhat lower than would be generated by a more fine-grained analysis.

Level Three Estimates:

These estimates are intended to depict annual expected building damage losses in the year 2000 if the "most effective" mitigations examined in this study are applied to the management of each hazard. The "most effective" mitigation for any hazard is, by definition, that mitigation which produces the largest loss reduction in the year 2000, regardless of its economic and/or political feasibility. These estimates should be considered as representing the lowest attainable loss levels. The mitigations used to produce these estimates are depicted in Figure 5-1.

Level Four Estimates:

Utilizing gross methods for assessing the cost feasibility of alternative loss reducing strategies, these estimates are intended to represent the loss levels which will be experienced in 2000 if the nation adopts and enforces those natural hazard management policies which will both reduce annual expected losses by the largest amount and -- at the same time -- accomplish this end without imposing annual mitigation costs which are higher than the annual loss reductions expected to be achieved through application of the mitigation. The mitigations which were used to produce these "cost feasible" loss estimates are depicted in Figure 5-2.

Level Five Estimates:

These estimates are intended to represent the loss levels which will be experienced in 2000 if the nation adopts and enforces those natural hazard management policies which will produce the highest annual net loss reduction. For any specific hazard such a reduction is defined as the largest difference between the actual annual loss reduction achievable through use of any mitigation and the annualized cost of that mitigation.

The methods and assumptions utilized in the preparation of these five sets of building damage loss estimates for the year 2000 are the major subjects of this chapter.

Loss Reduction Analysis, by Type of Technology

Five major types of loss-reducing technologies were considered in this study, including: Avoidance, Area Structural Protection, Building Strengthening, Site Preparation, and Building Removal Strategies. Specific technologies exemplary of these several types, together with their potential application to each of the nine natural hazards examined in this report are depicted in Figure 5-3. The

HAZARD	MITIGATION
1. HURRICANE WINDS 2. TORNADO 3. SEVERE WINDS	INCREASE DESIGNED WIND RESISTANCE CAPABILITY OF NEW BUILDINGS TO LEVEL EQUALLING 3.0 x THE LEVEL SPECIFIED IN THE UNIFORM BUILDING CODE (UBC). APPLY THE MITIGATION TO ALL NEW BUILDINGS CONSTRUCTED AFTER 1979.
4. EARTHQUAKE	INCREASE STRENGTH OF NEW BUILDINGS TO LEVEL REQUIRED IN 1973 UBC FOR EARTHQUAKE ZONE #3. APPLY MITIGATION TO ALL NEW BUILDINGS CONSTRUCTED IN SEISMICALLY ACTIVE ZONES AFTER 1979
5. EXPANSIVE SOILS	REQUIRE APPLICATION OF CHEMICAL SOIL STABILIZATION TECHNIQUES TO ALL RESIDENTIAL CONSTRUCTION SITES, OR IMPROVED FOUNDATION DESIGN. APPLY MITIGATION TO ALL NEW RESIDENTIAL CONSTRUCTION IN "LOW," "MODERATE," AND "HIGH" EXPANSIVE SOILS ZONES AFTER 1979.
6. LANDSLIDE	REQUIRE SOILS TESTING AND IMPROVED SITE-GRADING STANDARDS IN ALL LANDSLIDE-PRONE AREAS. APPLY MITIGATION TO NEW CONSTRUCTION AFTER 1979.
7. TSUNAMI	PERMIT ZERO NET RESIDENTIAL GROWTH IN TSUNAMI PRONE AREAS AFTER 1979.
8. STORM SURGE	CONSTRUCT SEA WALLS TO PROTECT FOUR (4) ADDITIONAL COUNTIES EACH YEAR FROM 100-YEAR STORM SURGE HEIGHTS. BEGIN CONSTRUCTION IN 1980, IN ORDER OF DECREASING DAMAGES IN AFFECTED COUNTIES.
9. RIVERINE FLOOD-ING	BETWEEN 1970 AND 1980, CONSTRUCT AREA FLOOD CONTROL FACILITIES TO PROTECT 200 ADDITIONAL CITIES EACH YEAR FROM FIFTY-YEAR FLOOD LEVELS. THEREAFTER SUSPEND ALL CONSTRUCTION OF FLOOD CONTROL FACILITIES AND APPLY THE FOLLOWING MITIGATIONS: (1) PROHIBIT ALL NET NEW GROWTH IN 100-YEAR FLOODPLAIN: (2) PURCHASE AND REMOVE ALL STRUCTURES FROM 2-10 YEAR FLOOD PLAINS.

Figure 5-1. Most Effective Mitigation, By Hazard

HAZARD	MITIGATION
1. HURRICANE WINDS 2. TORNADO 3. SEVERE WINDS	FOR NEW BUILDINGS CONSTRUCTED AFTER 1979 IN 229 COST - FEASIBLE COUNTIES [TABLE 5-22], INCREASE DESIGNED WIND RESISTANCE CAPABILITY TO LEVEL EQUALLING 1.5x THE LEVEL SPECIFIED IN THE UNIFORM BUILDING CODE. IN THE COST-FEASIBLE SUBSET NUMBERING 72 OF THESE SAME COUNTIES [TABLE 5-22], INCREASE DESIGNED WIND RESISTANCE CAPABILITY TO LEVEL EQUALLING 3.0x THE LEVEL SPECIFIED IN THE UNIFORM BUILDING CODE.
4. EARTHQUAKE	CONTINUE APPLICATION OF UBC EARTHQUAKE ZONE #3 LATERAL FORCE REQUIREMENTS IN ALL CALIFORNIA COUNTIES AND EXTEND REQUIREMENTS TO THE TWO NON-CALIFORNIA COUNTIES IN WHICH THIS MITIGATION IS COST-FEASIBLE [TABLE 5-22]
5. EXPANSIVE SOILS	APPLY CONSTRUCTION SITE MOISTURE CONTROL TECHNIQUES IN AREAS WHERE THE BUILDING SEASON IS MARKED BY WIDE VARIABILITY IN RAINFALL LEVELS
6. LANDSLIDE	REQUIRE SOILS TESTING AND IMPROVED SITE-GRADING TECHNIQUES IN ALL LANDSLIDE-PRONE AREAS. APPLY MITIGATION TO NEW CONSTRUCTION AFTER 1979.
7. TSUNAMI	PERMIT ZERO NET RESIDENTIAL GROWTH IN TSUNAMI PRONE AREAS AFTER 1979
8. STORM SURGE	REQUIRE FOUR (4) FOOT FLOODPROOFING OF ALL NEW STRUCTURES ADDED TO SURGE-PRONE ZONES (20' OR LESS, ADJUSTED MEAN SEA LEVEL) AFTER 1979. CONFINE THE USE OF THE MITIGATION TO THE ONE-HALF OF THE STORM SURGE AREA IN WHICH THIS MITIGATION IS ESTIMATED TO BE COST-FEASIBLE.
9. RIVERINE FLOOD-ING	PROVIDE AREA FLOOD CONTROL FACILITIES SUFFICIENT TO PROTECT ALL FLOOD-PRONE COMMUNITIES FROM FIFTY YEAR FLOOD LEVELS.

Figure 5-2. Most Effective Cost-feasible Mitigation, by Hazard

TECHNOLOGY BY CLASS AND TITLE	HAZARD TO WHICH APPLICABLE								
	RIVERINE FLOODING	STORM SURGE	TSUNAMI	HURRICANE	TORNADO	SEVERE WIND	EARTHQUAKE	LANDSLIDE	EXPANSIVE SOIL
1.0 Hazard Avoidance Strategies and Technologies									
1.1 Zero growth on fifty-year flood plains after 1980		●	●						
1.2 Zero growth on 100-year flood plains after 1980		●	●						
1.3 Zero growth on fifty-year riverine flood plains in specified additional numbers of flood-prone cities each year, to 2000	●								
1.4 Zero growth in counties exhibiting high Tornado Strike Risk (greater than 10^{-4} tornado strikes per year per square mile).					●				
2.0 Area Structural Protection Strategies									
2.1 Structural protection (dams, levees, etc) of cities with riverine flood problems.	●								
2.2 Construction of sea-walls to protect four additional counties per year from 100-year storm surge heights. Construct in order of decreasing damages in affected counties.		●							
3.0 Building Strengthening Strategies									
3.1 Require tie-downs on all mobile homes.				●	●	●			
3.2 Increase designed wind resistance capability of new buildings to level equalling 1.5 x the level specified in the Uniform Building Code (1.5 x UBC)				●	●	●			
3.3 Increase designed wind resistance capability of new buildings to level equalling 3.0 x the level specified in the Uniform Building Code (3 x UBC).				●	●	●			
3.4 Increase strength of new buildings to level required in UBC Earthquake Zone #3. (UBC 3).							●		
3.5 Floodproof 2% annually of all structures in fifty year riverine flood plains to provide zero damage to height of four feet.	●								
3.6 Floodproof 2% annually, of all structures in 100 year riverine flood plains to provide zero damage to height of four feet.	●								
3.7 After 1980, floodproof all new buildings in storm surge areas to height of four feet.		●							
3.8 Modify and retrofit existing buildings in high seismic risk areas to meet seismic safety standards.							●		
4.0 Site Preparation Strategies									
4.1 Require soils testing and improved site grading standards in landslide-prone areas.								●	
4.2 Require soils testing and pre-construction moisture control and/or soil stabilization on construction sites.									●
5.0 Building Removal Strategies									
5.1 Purchase and/or condemn and accelerate removal of high vulnerability structures in high hazard areas.	●	●	●				●	●	

Figure 5-3. Hazard-mitigating Technologies, by Type and Applicability to Nine Natural Hazards

loss-reducing capabilities of the several specific mitigations in each class are discussed in a later section, entitled "Loss Reduction Analysis, by Hazard."

Avoidance Strategies

As noted in Chapter IV, improvident patterns of interstate population migration and capital investment are the major reasons for the projected $4 billion increase in natural hazard building damage losses between 1970 and the year 2000. The large projected thirty-year increases in building wealth additions in high damage rate states and counties, principally along the Gulf Coast and South Atlantic, account for the major fraction of the large increases in annual expected natural hazard losses between 1970 and 2000. [See Table 4-19, 4-22]. Loss-accelerating patterns of inter-state migration are matched by similar movements of population and building investments to high-hazard areas internal to states and counties. If past patterns of development continue in the future, substantial increases in natural hazard losses will be the inevitable consequence. For example, if community growth in riverine flood plains continues in the future as it has in past decades, building damage losses from riverine floods can be expected to jump from an annual expected value of $1502 million in 1980 to $2634 million in the year 2000, assuming that no mitigations of any type are applied to deal with this situation during that period. Specifically, this loss estimate assumes that the construction of area flood control works is halted in 1980, that no regulation of growth in flood plains occurs thereafter, and that no building floodproofing mitigations are applied. Similarly, if continued development occurs in areas subject to storm surge and hurricane wind hazards, annual expected building damage losses from these phenomena can be expected to jump from $1127.5 million in 1970 to $2918 million in 2000.

Accordingly, this study sought to determine the natural hazard loss reductions which could be achieved in 2000 through use of a selected set of hazard avoidance policies. The impact of four such policies on annual expected hazard losses in the year 2000 are depicted in Table 5-2. As shown there, avoidance policies, alone, could produce a 24.4 percent reduction in estimated building damage losses in 2000 from tornado, tsunami, storm surge, and riverine flooding. Totalling $1441.8 million, this annual loss reduction is equal to 13.2 percent of the estimated level #1 building damage loss estimates for all hazards in that year.

ADVANCED STRATEGY	HAZARD	ANNUAL EXPECTED BUILDING DAMAGE LOSSES (1000's $)			
		2000 BASELINE LOSS	2000 LOSS WITH USE OF STRATEGY	LOSS REDUCTION	
				TOTAL	%
1. ZERO GROWTH IN COUNTIES AT RISK OF MORE THAN 10^{-4} TORNADO STRIKES PER YEAR PER SQUARE MILE[1]	TORNADO	2060.0	1812.8	247.2	12.0%
2. ZERO RESIDENTIAL GROWTH ON TSUNAMI 100-YEAR FLOOD PLAINS AFTER 1980[2]	TSUNAMI	27.9	27.1	0.8	2.87%
3. ZERO GROWTH OF ALL TYPES ON 100-YEAR STORM SURGE FLOOD PLAINS AFTER 1980[3]	STORM SURGE	1177.1	912.3	264.8	22.5%
4. ZERO NET GROWTH IN 100-YEAR RIVERINE FLOOD PLAINS BETWEEN 1980-2000[4]	RIVERINE FLOODING	2634.0	1694.21	939.8	35.7%
TOTALS	--	5899.0	4446.41	1452.6	24.62%

1. Hart, Gary C."Natural Hazards: Tornado, Hurricane, Severe Wind Loss Models," Redondo Beach, California: J.H. Wiggins Company, December 1976.

2. Lee, Larry T. Jon D. Chrostowski, and Ronald T. Eguchi, "Natural Hazards: *Riverine Flooding, Storm Surge, Tsunami Loss Models*," Redondo Beach, California: J.H. Wiggins Company, June 1976, Table 4-5.

3. Ibid., Table 3-3.

4. Calculated from data presented in Lee, et. al., 1976. See, also Table 5-5, this report.

Table 5-2. Estimated Payoffs in 2000 AD from Use of Selected Avoidance Strategies to Reduce Annual Expected Losses from Tornado, Tsunami, Storm Surge, and Riverine Flooding

Loss reductions associated with avoidance mitigations for tornado, tsunami, and storm surge were derived directly from the computer loss models used by Hart, [1976], and Lee, et.al. [1976]. For riverine flooding, the loss reductions were calculated from computer model outputs, as follows: (a) building wealth values and building damage losses in all six flood zones were determined for 1970 and 2000 [See Tables 5-3, 5-4]; (b) building damage rates for each flood zone then were calculated from these data; and (c) the building damage rate for zone F (area outside 100-year flood plain) was applied to the projected 1980 to 2000 increase in building wealth to flood prone communities. The latter was determined from the average value of buildings shown in Tables 5-3 and 5-4 and from the building population data presented in Lee, et. al., Table 2-27, and, from the 1980 baseline conditions depicted in Tables 5-23(a) and 5-23(b).

VARIABLE	ZONE A 2-5 YR. FLOOD	ZONE B 5-10 YR. FLOOD	ZONE C 10-25 YR. FLOOD	ZONE D 25-50 YR. FLOOD	ZONE E 50-100 YR. FLOOD	ZONE F 100 YR.+ FLOOD	TOTAL	ZONES A-D 50 YR. FLOOD
1. AVERAGE VALUE, RESIDENTIAL UNITS(a)	11,640	13,296	15,860	15,860	15,860	15,860	--	--
2. AVERAGE VALUE, COMMERCIAL-INDUSTRIAL-GOV'T UNITS(a)	184,000	184,000	184,000	184,000	184,000	184,000	--	--
3. RESIDENTIAL UNITS AS PERCENT OF ALL UNITS(b)	61.57	61.57	61.57	61.57	61.57	61.57	61.57	61.67
4. EXPOSED UNITS, ALL TYPES (1000's)(c)	614.8	683.1	910.8	1,115.7	1,229.6	4,554	9,108	2,324.4
5. AVERAGE VALUE, ALL UNITS	78,061.95	79,081.55	80,660.20	80,660.20	80,660.20	80,660.20	80,366.42	79,855.32
6. TOTAL BUILDING VALUE ($MILLIONS)	47,992.5	54,020.61	73,465.31	89,992.59	99,179.78	367,326.55	731,977.34	265,471.01
7. BUILDING LOSSES,(d) ($MILLIONS)	758.3	392.6	287.9	159.8	111.8	190.6	1,901.0	1,598.6
8. BUILDING DAMAGE RATE (%)	1.58	0.7268	0.3919	0.1776	0.1127	0.0519	0.2594	0.6022

Source: (a) Row 1-2 values calculated from data presented in Lee., et.al (1976), Tables 2-8, 2-15, and page 42.
(b) Calculated from data presented in Lee, et.al (1976), Tables 2-9 and 2-27.
(c) Lee, et.al (1976), Table 2-26 and 2-4.
(d) Calculated from data presented in Lee., et.al. (1976), Table 2-28 and project computer printouts related thereto.

Table 5-3. Building Exposures, Losses and Building Damage Rates, by Flood Zone in Flood Prone Communities, 1970

VARIABLE	ZONE A 2-5 YR. F.P.	ZONE B 5-10 YR. F.P.	ZONE C 10-25 YR. F.P.	ZONE D 25-50 YR. F.P.	ZONE E 50-100 YR. F.P.	ZONE F 100 YR.+ F.P.	TOTAL	ZONES A-D 50 YR. F.P.
1. TOTAL BUILDINGS EXPOSED(a) (1000's)	728.3	809.3	1,079.0	1,321.8	1,456.6	5,395	10,790	3,938.4
2. AVERAGE VALUE(b)	78,061.95	79,081.55	80,660.20	80,660.20	80,660.20	80,660.20	80,336.42	79,855.32
3. TOTAL BUILDING VALUE ($MILLION)	56,852.52	64,000.70	87,032.36	106,616.65	117,489.65	435,161.78	867,153.66	314,502.23
4. BUILDING LOSSES(c) ($MILLION)	475.061	277.492	238.074	163.311	129.885	218.614	1,502.5	1,154.00
5. BUILDING DAMAGE RATE (%)	0.8356	0.4336	0.2736	0.1532	0.1106	0.0502	0.1733	0.3669

Source: (a) Lee. et.al. (1976), Tables 2-9 and 2-27, Run III. This run has no population growth diversion from floodplains between 1970-80, but did assume extension of fifty-year area flood protection to 200 communities per year, 1970-1980.
(b) Table 5-3.
(c) Lee. et.al. (1976), Table 2-28, Run III, and supporting computer print-out.

Table 5-4. Building Exposures, Losses & Building Damage Rates, by Flood Zone, in Flood Prone Communities, 1980

As shown in Table 5-5a, these calculations reveal that annual expected building damage losses from riverine floods in 2000 may be held to $1694 million if net new construction in 100-year floodplains is avoided between 1980 and 2000, even if the construction of new area flood control works is suspended during that period, and even if no other mitigations are employed to reduce losses within the 100-year floodplain.

	1980			2000		
	ZONES A-E	ZONE F	TOTAL	ZONES A-E	ZONE F	TOTAL
TOTAL STRUCTURES EXPOSED (1000's)*	5331.0	5459.0	10,790	5331	10,393	15,729
TOTAL VALUE OF STRUCTURES($MILLIONS)**	$426,809.31	440,324.03	--	426,809.31	838,704.76	--
AVERAGE VALUE OF STRUCTURES	$79,855.32	80,660.2	--	79,855.32	80,660.2	--
BUILDING DAMAGE RATE (%)**	0.2966	0.05105	--	0.2966	0.05105	
ESTIMATED LOSS ($MILLIONS)***	1266.05	224.76	1490.81	1266.05	428.16	1694.21

*Derived from Lee, et. al. (1976), Table 2-27. See also Tables 5-23(a), 5-23(b), this report.
**Derived from Tables 5-23(a), 5-23(b)
***Calculated from values presented in lines 1, 3, 4

Table 5-5a. Impact of 100-year Floodplain Avoidance Policy on Annual Expected Building Damage Losses in 2000

The total economic and non-economic losses associated with use of the "most effective" mitigation for riverine floods and tsunami are presented in Tables 5-5b, 5-5c.

VARIABLE	ANNUAL EXPECTED LOSS, 2000		LOSS REDUCTION	
	NO MITIGATION	MOST EFFECTIVE MITIGATION	$	%
1. BUILDING DAMAGE* (1970$)	2634	953.4	1680.6	63.8
2. BUILDING CONTENTS* VALUE (1970$)	2599.13	940.78	1658.35	63.8
3. INCOME* (1970$)	14.35	5.19	9.16	63.8
4. SUPPLIER COSTS* (1970$)	.17	.06	.11	64.7
SUBTOTAL* (1970$)	5247.65	1899.2	3348.22	63.8
5. HUMAN LIVES	263	95	168	63.9
6. HOUSING UNITS	--	--	--	--
7. HOME USE (PERSON YEARS)	--	--	--	--
8. EMPLOYMENT (PERSON YEARS)	2280.8	825.6	1455.2	63.8

*Millions

Table 5-5b. Annual Expected Flood Losses and Loss Reductions, Without Mitigation and With Most Effective Mitigation, Year 2000

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES				LOSS REDUCTION (MOST EFFECTIVE MITIGATION)	
			NO MITIGATION		MITIGATION			
	1970	2000	1970	2000	50 YR.F.P.	100 YR.F.P.	TOTAL	%
1. BUILDING VALUE* (1970$)	217,327	508,852	8.7	19.8	19.7	19.5	.3	1.52
2. BUILDING CONTENTS* VALUE (1970$)	117,907	608,870	5.54	19.1	19.0	18.8	.3	1.57
3. INCOME* (1970$)	106,500	268,700	.727	1.479	1.453	1.433	.046	3.10
4. SUPPLIER COSTS* (1970$)	--	--	.0124	.0273	.0266	.0263	.0010	3.66
SUBTOTAL* (1970$)	--	--	14.98	40.41	40.18	39.76	.647	1.60
5. HUMAN LIVES	18,200,851	23,606,782	20	44	44	43	1	2.27
6. HOUSING UNITS	6,340,000	9,410,000	234	335	333	329	6	1.79
7. HOME USE (PERSON YEARS)	--	--	345	389	380	376	13	3.34
8. EMPLOYMENT (PERSON YEARS)	--	--	97.5	195.9	193.1	189.8	6.1	3.11

*Millions

Table 5-5c. Annual Expected Tsunami Losses and Loss Reductions, 1970-2000, Based on Application of Zero Residential Growth Policy in Tsunami Zones.

Area Structural Protection Strategies

All other things being equal, it seems clear that the hazard-proneness of any given area or site may be reduced through construction of protective facilities to reduce the vulnerability of the site to one or more specific hazards. Flood control dams, levees, channel improvements, sea walls, revetments, and similar constructed systems are exemplary of this approach.

In this study, the flood control model revealed that annual expected losses for 1970 were approximately $1 billion below the value estimated for the modeled cities, had no flood control facilities been provided in prior years to protect the communities which were included in the model. The same riverine flood model showed that the annual expected building damage loss for 2000 ($2634 million) could be reduced to approximately $1653 million by equipping all flood-prone cities with 50-year area flood protection facilities.

Similarly, if counties subject to storm surge losses are protected from this hazard through construction of sea walls capable of handling 100-year surge heights, annual expected losses from this hazard in the year 2000 can be reduced substantially. If four counties per year are so protected, in decreasing order of their annual expected storm surge damage losses, then annual expected storm surge losses in 2000 may be reduced from $1177.1 million to $334.8 million, even if no other mitigations are applied to deal with this hazard.

Building Strengthening Strategies

Substantial reductions in damage rates for selected mixes of buildings can be achieved through use of building strengthening technologies. Accordingly, four possible technology-forcing building code modifications were considered in this inquiry. The first involves modification of all U.S. Building Codes so as to impose 1973 Uniform Building Code, Zone 3 Earthquake standards to all structures constructed after 1980 in the United States in the seismically-active areas mapped in that code. The second involves the imposition of new construction standards producing 1.5 times the wind resistance level now required in the Uniform Building Code. The third involves the imposition of new construction standards producing 3.0 times the wind resistance level now specified in the Uniform Building Code. The fourth involves the requirement that all buildings in riverine flood plains be subject to floodproofing to a height of 4 feet.

In the year 2000, enforcement of the most rigorous code modifications could reduce annual expected dollar losses of all types from $10,352.7 to $8,027.0 million for earthquake, tornado, hurricane, and severe wind. [See Tables 5-6, 5-7]

HAZARD	ANNUAL EXPECTED LOSSES*				REDUCTION WITH MOST EFFECTIVE MITIGATION	
	NO MITIGATION	UBC ZONE 3 EARTHQUAKE STANDARDS	UBC x 1.5 WIND RESISTANCE STANDARDS	UBC x 3.0 WIND RESISTANCE STANDARDS	TOTAL	%
1. EARTHQUAKE	1177	1084	NOT APPLICABLE	NOT APPLICABLE	93.0	7.90
2. TORNADO	2058	NOT APPLICABLE	1746	1564	494.0	24.00
3. HURRICANE WIND	1742	NOT APPLICABLE	1453	1280	462.0	26.52
4. SEVERE WIND	24.8	NOT APPLICABLE	21.2	19.1	5.7	23.00
TOTALS	5001.8	1084	3220.2	2863.1	1054.7	21.09

Source - Tables 5-8, 5-9, 5-10, 5-11 *Millions of 1970$

Table 5-6. Annual Expected Building Damage Losses and Loss Reductions in 2000 as a Function of Specified Mitigations for Four Hazards

VARIABLE	ANNUAL EXPECTED LOSS, 2000		LOSS REDUCTION	
	NO MITIGATION	MOST EFFECTIVE MITIGATION	TOTAL	[illegible]
1. BUILDING DAMAGE* (1970$)	5,001.8	3,947.1	1,054.7	21.09
2. BUILDING CONTENTS* VALUE (1970$)	4,302.6	3,294.9	1,007.7	23.42
3. INCOME* (1970$)	1,035.8	777.2	258.6	24.97
4. SUPPLIER COSTS* (1970$)	12.24	7.76	4.48	36.60
SUBTOTAL* (1970$)	10,352.7	8,027.0	2,325.7	22.46
5. HUMAN LIVES	1,484	1,185	299	20.15
6. HOUSING UNITS	127,992	98,173	29,819	23.30
7. HOME USE (PERSON YEARS)	157,583	117,773	39,810	25.26
8. EMPLOYMENT (PERSON YEARS)	206,279	155,259	51,020	24.73

Source: Calculated from data presented in Tables 5-8 to 5-11
*Millions

Table 5-7. Annual Expected Losses of All Types Under Various Conditions of Exposure to Earthquake, Tornado, Hurricane, and Severe Wind Hazards, 2000

The use of these "most effective" building strengthening mitigations is expected to reduce annual losses in 2000 by 7.9 percent for earthquake [See Table 5-8]; by 24.0 percent for tornado [See Table 5-9]; by 26.5 percent for hurricane [See Table 5-10]; and by 23.0 percent for severe winds [See Table 5-11].

Since the loss reduction analysis assumed that enforcement of these mitigations would be limited to new structures constructed after 1980, the estimated loss reduction cited above fails to indicate the real scope of the improvement possible through the use of building strengthening technologies. For example, had these same technologies been applied at the time of their construction to all buildings which were in place in 1970, expected annual losses in that year from earthquakes, tornadoes, hurricanes, and severe winds could have been reduced by increments ranging from 40.82 percent (hurricane) to 50.88 percent (severe winds). [See Tables 5-12 and 5-13]

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES			LOSS REDUCTION	
	1970	2000	1970	2000 (WITHOUT MITIGATION)	2000 (WITH MITIGATION)	TOTAL	%
1. BUILDING VALUE * (1970$)	1,494,293.0	3,577,016.0	655.2	1,177.0	1,084	93	7.90
2. BUILDING CONTENTS* VALUE (1970$)	858,053.0	4,466,392.0	123.23	372.8	341	32	8.58
3. INCOME* (1970$)	757,428.0	1,953,000.0	2.65	3.91	3.62	.283	7.25
4. SUPPLIER COSTS * (1970$)	--	--	.030	.048	.043	.005	11.37
SUB-TOTAL* (1970$)	--	--	781.1	1,553.7	1,428.7	125	8.05
5. HUMAN LIVES	143,169,495.0	182,491,865.0	272	400	370	30	7.50
6. HCUSING UNITS	47,790,000.0	69,960,000.0	20,485	22,888	20,585	2,303	10.06
7. HOME USE (PERSON YEARS)	--	--	736	648	597	51	7.87
8. EMPLOYMENT (PERSON YEARS)	--	--	414	635	585	50	7.86

*millions

Table 5-8. Annual Expected Earthquake Losses and Loss Reductions, 1970-2000, Based on Application of UBC Zone 3 Construction Standards to All Structures Built after 1979

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES				LOSS REDUCTION (MOST EFFECTIVE MITIGATION)	
			NO MITIGATION		WITH BLDG. CODE MITIGATION			
	1970	2000	1970	2000	2000 (1.5xUBC)	2000 (3.0xUBC)	TOTAL	%
1. BUILDING VALUE * (1970$)	1,788,989	4,300,491	879.8	2,058	1,746	1,564	494	24.00
2. BUILDING CONTENTS* VALUE (1970$)	1,065,396	5,539,277	469.9	2,401	2,043	1,828	573	23.87
3. INCOME * (1970$)	917,200	2,421,000	302.8	751	637	569	182	24.23
4. SUPPLIER COSTS* (1970$)	--	--	3.451	9.042	6.943	5.750	3.292	36.41
SUBTOTAL* (1970$)	--	--	1,656.0	5,219.0	4,432.9	3,966.7	1,252.3	24.00
5. HUMAN LIVES	181,198,749	228,720,498	392	920	781	694	226	24.57
6. HOUSING UNITS	60,010,000	86,990,000	36,212	52,119	44,081	39,303	12,816	24.59
7. HOME USE (PERSON YEARS)	--	--	86,122	107,650	91,120.1	81,542	26,108	24.25
8. EMPLOYMENT (PERSON YEARS)	--	--	57,541.0	146,569.0	124,610	110,774	35,795	24.42

*millions

Table 5-9. Annual Expected Tornado Losses and Loss Reductions, 1970-2000, Based on Application of More Stringent UBC Wind Resistance Construction Standards to All Structures Built after 1979

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES				LOSS REDUCTION (MOST EFFECTIVE MITIGATION)	
			NO MITIGATION		WITH BLDG. CODE MITIGATION			
	1970	2000	1970	2000	2000 (1.5xUBC)	2000 (3.0xUBC)	TOTAL	%
1. BUILDING VALUE* (1970$)	682,476	1,680,245	685.5	1,742	1,453	1,280	462	26.52
2. BUILDING CONTENTS* VALUE (1970$)	379,800	2,038,041	267.6	1,505	1,256	1,105	400	26.58
3. INCOME* (1970$)	343,400	913,000	101.8	276.2	229	201	75.2	27.23
4. SUPPLIER COSTS* (1970$)	--	--	1.09	3.10	2.37	1.93	1.17	37.74
SUBTOTAL* (1970$)	--	--	1,056.0	3,526.3	2,988.1	2,587.9	938.4	26.61
5. HUMAN LIVES	62,741,264	83,615,242	62	153	127	112	41	26.80
6. HOUSING UNITS	20,720,000	31,890,000	31,885	52,237	43,130	37,713	14,524	27.80
7. HOME USE (PERSON YEARS)	--	--	34,505	48,271	39,857	34,860	13,411	27.78
8. EMPLOYMENT (PERSON YEARS)	--	--	21,004	58,224	48,839	43,242	14,982	25.73

*millions

Table 5-10. Annual Expected Hurricane Losses and Loss Reductions, 1970-2000, Based on Application of More Stringent UBC Wind Resistance Construction Standards to All Structures Built After 1979

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES				LOSS REDUCTION (MOST EFFECTIVE MITIGATION)	
			NO MITIGATION		WITH BLDG. CODE MITIGATION			
	1970	2000	1970	2000	2000 (1.5xUBC)	2000 (3.0xUBC)	TOTAL	%
1. BUILDING VALUE* (1970$)	2,064,507	4,924,075	11.4	24.8	21.2	19.1	5.7	23.0
2. BUILDING CONTENTS* VALUE (1970$)	1,207,498	6,252,952	4.5	23.8	22.0	20.9	2.9	12.2
3. INCOME* (1970$)	1,053,000	2,753,000	2.09	4.70	4.02	3.61	1.09	23.2
4. SUPPLIER COSTS* (1970$)	--	--	.021	.051	.040	.034	.017	33.3
SUBTOTAL* (1970$)	--	--	18.01	53.35	47.26	43.64	9.7	18.2
5. HUMAN LIVES	203,260,531	256,179,160	5	11	10	9	2	18.2
6. HOUSING UNITS	67,560,000	97,770,000	547	748	640	572	176	23.5
7. HOME USE (PERSON YEARS)	--	--	852	1,014	865	774	240	23.7
8. EMPLOYMENT (PERSON YEARS)	--	--	373	851	727	658	193	22.7

*millions

Table 5-11. Annual Expected Losses and Loss Reductions from Severe Winds, 1970-2000, Based on Application of More Stringent UBC Wind Resistance Construction Standards to All Structures Built After 1979

BUILDING MIX	BUILDING DAMAGE RATE FOR SPECIFIED HAZARD (ANNUAL EXPECTED DAMAGE ÷ BUILDING VALUE)			
	EARTHQUAKE (RATE x 10^{-3})	TORNADO (RATE x 10^{-3})	HURRICANE (RATE x 10^{-2})	SEVERE WIND (RATE x 10^{-3})
1. 1970 MIX OF BUILDINGS	0.438468	0.491786	0.100443	.005522
2. 2000 MIX OF BUILDINGS	0.329045	0.47855	0.103675	.005036
3. NEW BUILDINGS CONSTRUCTED TO UBC ZONE 3 EARTHQUAKE STANDARDS	0.250537	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
4. NEW BUILDINGS CONSTRUCTED TO UBCx1.5 WIND RESISTANCE STANDARDS	NOT APPLICABLE	0.344893	0.076922	.003427
5. NEW BUILDINGS CONSTRUCTED TO UBCx3.0 WIND RESISTANCE STANDARDS	NOT APPLICABLE	0.272427	0.059583	.002693

Source: Calculated from data presented in Tables 5-8 to 5-11.

Table 5-12. Building Damage Rates from Selected Mixes of Buildings Exposed to Earthquake, Tornado, Hurricane and Severe Wind

CONDITIONS		ANNUAL EXPECTED LOSS (MILLIONS OF DOLLARS) IN INDICATED YEAR FOR SPECIFIED HAZARD UNDER INDICATED CONDITION			
		EARTHQUAKE	TORNADO	HURRICANE	SEVERE WIND
1. ACTUAL CONDITIONS, 1970		655.2	879.8	686	11.4
2. UBC ZONE 3 EARTHQUAKE STANDARDS IN ALL AREAS OF THE U.S.		374	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
3. UBC X 1.5 IN ALL AREAS OF THE U.S.		NOT APPLICABLE	617	525	7.1
4. UBC X 3.0 IN ALL AREAS OF THE U.S.		NOT APPLICABLE	487	406	5.6
MAXIMUM POSSIBLE SAVINGS UNDER MOST EFFECTIVE MITIGATION	N	281.2	392.8	280	5.8
	%	42.92	44.65	40.82	50.88

Source: Calculated from building damage rates presented in Table 5-12 and from 1970 building values presented in Tables 5-8 to 5-11

Table 5-13. Annual National Expected Building Damage Losses from Exposure to Earthquake, Tornado, Hurricane, and Severe Wind Under Various Conditions of Building Strength,1970.

Substantial loss reductions also can be achieved through application of floodproofing standards to buildings located in 100-year riverine and storm surge floodplains. As shown in Table 5-14, a four-foot floodproofing mitigation reduces storm surge losses in the year 2000 by nearly 59%. Similarly, the riverine flood model suggests that between 1980 and 2000, four-foot floodproofing of 40 percent of the structures located in structurally-protected 100-year riverine flood plains can reduce annual expected building damage losses in 2000 by approximately 16.6 percent.

VARIABLE	NATIONAL VALUE AT RISK		ANNUAL EXPECTED LOSSES			LOSS REDUCTION (MOST EFFECTIVE MITIGATION)	
			NO MITIGATION		2000 FLOOD PROOFING MITIGATION		
	1970	2000	1970	2000		TOTAL	%
1. BUILDING VALUE* (1970$)	438,733	1,061,972	442.0	1,176	479	697	59.27
2. BUILDING CONTENTS* VALUE (1970$)	238,241	1,275,127	197	1,160	479	681	58.71
3. INCOME* (1970$)	222,700	581,300	2.367	6.407	2.660	3.747	58.48
4. SUPPLIER COSTS* (1970$)	--	--	.028	.077	.049	.028	36.19
SUBTOTAL* (1970$)	--	--	641.4	2,342,5	960.7	1,381.8	58.99
5. HUMAN LIVES	38,387,247	51,328,807	37	103	42	61	59.22
6. HOUSING UNITS	12,890,000	19,890,000	24,521	43,757	16,917	26,882	61.43
7. HOME USE (PERSON YEARS)	--	--	7,290	10,330	3,989	6,341	61.38
8. EMPLOYMENT (PERSON YEARS)	--	--	370	1,018	511	507	49.80

*millions

Table 5-14. Annual Expected Storm Surge Losses and Loss Reductions, 1970-2000, Based on Application of Four-foot Floodproofing Standards to New Buildings Constructed After 1979

Building Removal Strategies

An additional strategy considered for reducing natural hazard losses was one involving the public purchase and removal of structures from high hazard areas. Riverine floodplains were selected for examination of the possible cost feasibility of this strategy.

As shown in Tables 5-15 and 5-25, more than 60 percent of all 1970 annual expected building damage losses from riverine floods was produced by buildings located in the two - ten year segments of the nation's riverine floodplains. Not including the value of the land on which these structures were located, the aggregate worth of these structures was equal to slightly less than the sum of 89 years of the annual losses expected to be sustained by these same structures. Public purchase and removal of these structures to flood Zone F in 1970 would have reduced total flood losses in that year by approximately $1098.8 million and would have liberated much "open space" and potential park land for urban use. Even if land values were equal to fifty percent of the value of the structures in these flood zones, the expected annual reduction in building damage flood losses when combined with the recreational and aesthetic benefits associated with public ownership of these lands might well make this strategy attractive in some areas.

FLOODPLAIN ZONE	BUILDING WEALTH			ANNUAL EXPECTED BLDG. DAMAGE LOSS)		
	N ($MILLIONS)	%	CUM %	N ($MILLIONS)	%	CUM %
ZONE A (2-5 YEAR RETURN)	47,992.50	6.56	6.56	758.3	39.9	39.9
ZONE B (5-10 YEAR RETURN)	54,020.61	7.38	13.94	392.6	20.7	60.6
ZONE C (10-25 YEAR RETURN)	73,465.31	10.04	23.98	287.9	15.2	75.8
ZONE D (25-50 YEAR RETURN)	89,992.59	12.29	36.27	159.8	8.4	84.2
ZONE E (50-100 YEAR RETURN)	99,179.78	13.55	49.82	111.8	5.9	90.1
ZONE F (OUTSIDE 100 YEAR FLOODPLACE)	367,326.55	50.80	100.00	190.6	9.9	100.0
ALL ZONES	731,977.34	100.00	100.00	1,901.0	100.0	100.0

Table 5-15. Building Wealth and Building Damage Losses, 1970, by Riverine Floodplain Zone

As a supplement or alternative to the above-described building removal strategy, consideration also might be given to application of this strategy to selected flood-insured structures which experienced damage from any given flood event.

Structures which might be targeted for such removal could be those which meet specific criteria based on the size of the insurance claim, and the annual expected future damage rate for the repaired structure in relation to the removal cost minus the amount of the insurance claim. In this study, no calculations were performed to determine the possible impact of this strategy.

Site Preparation Strategies

To deal with landslide and expansive soil hazards, two site preparation mitigations were tested. For landslide, the mitigation involved the enforcement of improved site grading and soils testing ordinances between 1980 and 2000. For expansive soils, the mitigation involved chemical stabilization of soils on new single-family dwelling unit sites between 1980 and 2000. Use of these mitigations result in the following loss estimates.

Hazard	2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction ($)	Loss Reduction (%)
Landslide	871.2	349.4	521.8	59.9%
Expansive Soils	997.1	760.1	237.0	23.8%
Totals	1868.3	1109.5	758.8	40.6%

Loss Reduction Analysis, by Type of Hazard

For each of the nine study hazards a most effective strategy or combination of strategies was devised. Without regard to their political or economic feasibility, these were the strategies that produced the largest reductions in annual expected losses for the year 2000 and are depicted in Figure 5-1, above. For earthquake, hurricane winds, severe winds, and tornado, these were the mitigations shown in Figure 5-1 and in Tables 5-7 to 5-11. For landslide and expansive soil, the most effective mitigations were those discussed under "Site Preparation Strategies" above. Similarly, for tsunami, the most effective strategy was that discussed under "Avoidance Strategies," above. For storm surge, the most effective mitigation revealed by the loss reduction analysis was one which would involve the construction of sea walls capable of providing protection of surge-prone counties up to the 100-year surge height. The specific mitigation utilized in the analysis assumed that, between 1980 and the year 2000, four counties per year could be so protected, and that construction of such walls would proceed in order of decreasing volume of damages within each county. This mitigation provided a reduction in annual expected losses from storm surge in the year 2000, from $1177.1 million to a level of $334.8 million. However, four foot floodproofing of essentially all of the buildings in the storm surge zone produced nearly equal loss reductions. In the latter mitigation, the analysis revealed that storm surge losses could be reduced from $1177.1 to $471.5 million per year [See Table 5-14].

The most effective mitigation for riverine floods involved the joint use of the following mix of strategies: (a) provision of area flood protection facilities to 200 additional cities per year between 1970 and 1980; (b) application of "zero" net growth land use policies to the 100-year flood plains of all flood prone cities between 1980 and 2000; (c) removal of all structures from the 2-10 year floodplain by the year 2000. This combination of strategies produced an annual estimated riverine flood loss from damage to buildings which totalled $953.62 million for the year 2000. Annual expected riverine flood losses of all types in 2000 are as shown in Table 5-16. As indicated there, 2000 baseline losses are reduced by 63.8 percent through use of the above described "most effective" mitigation.

When these "most effective" mitigations are applied to all hazards in the year 2000, the annual expected building damage losses are as shown in Table 5-1, [See Column E]. Annual expected losses of all types are as shown in Tables 5-17 and 5-18.

CONDITION	ANNUAL EXPECTED LOSSES ($MILLIONS)			
	A BUILDING DAMAGE	B TOTAL (A x 1.99)	REDUCTION FROM BASELINE	
			$	%
(1) BASELINE CONDITIONS	2634	5241.66	--	--
(2) LOSSES IF ALL PROJECTED GROWTH IN FLOOD ZONES A-E, 1980-2000, IS SHIFTED TO ZONE F	1694	3371.06	1870.6	35.7%
(3) LOSSES IF CONDITION #2 EXISTS AND ALL 1980 BUILDINGS IN FLOOD ZONES A AND B OF "UNPROTECTED" COMMUNITIES ARE REMOVED AND REPLACED BY STRUCTURES IN ZONE F	1329.75	2646.21	2595.45	49.5%
(4) LOSSES IF CONDITION #2 EXISTS AND ALL 1980 BUILDINGS IN ALL ZONES A AND B ARE REMOVED AND REPLACED BY STRUCTURES IN ZONE F	953.617	1897.7	3343.96	63.8%

Table 5-16. Total Annual Expected Riverine Flood Losses in 2000 Under Three Selected Mitigations

HAZARD	1970 DOLLAR LOSS (ALL TYPES)*	2000 DOLLAR LOSSES (ALL TYPES)*		ACHIEVABLE LOSS REDUCTION*	
		NO MITIGATION (LEVEL #1)	MOST EFFECTIVE MITIGATION (LEVEL #3)	$	%
EARTHQUAKE	781.1	1,553.7	1,428.7	125	8.05
EXPANSIVE SOILS	798.1	997.1	760.1	237	23.77
LANDSLIDE	370.3	871.2	349.4	521.8	59.89
HURRICANE	1,056.0	3,526.3	2,587.9	938.4	26.61
SEVERE WIND	18.0	53.4	43.64	9.7	18.2
TORNADO	1,656.0	5,219.1	3,966.7	1,252.3	24.00
RIVERINE FLOOD	2,758.3	5,241.7	1,897.3	3,344.4	63.8
STORM SURGE	641.2	2,342.9	960.7	1,381.8	58.99
TSUNAMI	15.00	40.4	39.73	.65	1.6

*($Millions)

Source: Tables 5-1, 5-5b, 5-5c, 5-8 to 5-11, 5-14.

Table 5-17. Annual Expected Dollar Losses of All Types for Nine Natural Hazards Under Two Conditions of Exposure, 2000

VARIABLE	ANNUAL EXPECTED LOSS, 2000		LOSS REDUCTION	
	NO MITIGATION	MOST EFFECTIVE MITIGATION	TOTAL	%
1. BUILDING DAMAGE* (1970$)	10,699.9	6,364.3	4,335.6	40.5
2. BUILDING CONTENTS* VALUE (1970$)	8,080.7	4,589.3	3,491.4	43.2
3. INCOME* (1970$)	1,058.0	785.7	272.3	25.7
4. SUPPLIER COSTS* (1970$)	12.5	7.9	4.6	37.1
SUBTOTAL* (1970$)	19,851.4	11,747.2	8,103.9	40.8
5. HOUSING UNITS	172,084	110,326	61,758	35.9
6. HOME USE (PERSON YEARS)	168,302	120,937	47,365	28.1
7. EMPLOYMENT (PERSON YEARS)	209,773.7	156,631.4	53,142.3	25.3

Source: Calculated from data 5-8 to 5-11, 5-14
*Millions

Table 5-18. Annual Expected Losses of All Types for Nine Natural Hazards Under Two Conditions of Exposure, 2000

The building damage loss reductions (in 1970 dollars) which are believed to be achievable in 2000 through use of selected hazard-specific mitigations are summarized below. In all cases the loss reductions have been calculated on the basis of the 2000 baseline loss estimates shown in Table 5-1 [Column B] and the reduced damage rates which are associated with use of the mitigations. Further details concerning these loss reduction estimates may be obtained from Chapters II and III and from three specific reports covering each of the hazards [See Wiggins, et. al., (1976); Hart (1976); and Lee, et. al. (1976)].

Earthquake

The loss reduction estimates for this hazard are a product of a two-part mitigation assumption: (a) that all new buildings constructed in California will continue to comply with the lateral force standards specified for 1973 UBC Earthquake Zone #3 structures; (b) that, after 1980, all new buildings constructed in all other areas of the U.S. which are mapped as seismically active in the same 1973 UBC will also comply with Zone #3 standards. The loss estimates resulting from these assumptions are:

	2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
California Counties	952.1	748.7	203.4	21.36%
All Other	426.4	335.3	91.1	21.36%
Total	1378.5	1084.0	294.5	21.36%

Expansive Soils

All expansive soils loss estimates for 2000 were calculated utilizing the following procedure: (a) county-level losses in 1970 were aggregated, by state, and then increased by the estimated 1970-2000 growth rate for the state; (b) the sum of the resulting state-level loss estimates then was used as the baseline for the 2000 loss reduction calculation; (c) the national 1970 loss estimate was reduced by ten percent to account for building retirements between 1980-2000; (d) the resulting value was subtracted from the 2000 baseline projection and the difference was assumed to be the loss chargeable to new residential construction between 1980-2000; (e) this value was reduced 85% to account for loss reductions achievable through use of soil stabilization techniques and by 10% to account for loss reduction achievable through use of construction-site moisture control techniques. The latter reduction assumed that moisture control techniques can reduce losses by thirty percent in areas where the building season is marked by wide variability in rainfall levels and that approximately thirty percent of all expansive soil-affected construction will be in such areas. The loss estimates resulting from these calculations are:

Mitigation #1 [Most Effective Mitigation]

Require application of soil stabilization techniques to all sites on which single family dwelling units are constructed after 1980. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
997.1	760.1	237.0	23.77%

Mitigation #2

Require application of moisture control techniques to soils on approximately thirty percent of all sites on which new single family dwelling units are constructed after 1980. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
997.1	969.2	27.9	2.8%

Landslide

The experience of the City of Los Angeles [See Chapter II, Landslides] suggests that adequate grading and soils analysis ordinances can reduce landslide losses by approximately 97%. Accordingly, the loss reduction estimates presented below assume that 2000 losses associated with new construction between 1980-2000 can be reduced 97%. The annual new construction baseline losses for that year were calculated using the procedure described, above, for expansive soils.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
871.2	349.4	521.8	59.9%

Riverine Flood

Mitigation #1:

This baseline mitigation assumes that flood control facilities are constructed to protect, from fifty-year flood heights, 200 additional cities each year between 1970 and 1980. Thereafter no mitigations of any type are applied. Building damage losses are as follows:

1970 Losses	$1901 million
1980 Losses	$1502 million
2000 Losses	$2634 million

Mitigation #2:

Apply Mitigation #1 through 1980, then shift all net additional community growth to areas outside the 100-year floodplain. Engage in no further construction of flood control projects. The resulting building damage losses appear below.

The calculations for this mitigation assumed: (1) that the building damage rate for Flood Zone F (the area outside the 100 year floodplain) is 0.05105% (see Tables 5-3, 5-25); (2) that the total building growth in flood prone cities between 1980 and 2000 will be 4,939,000 net new units [See Tables 5-5a, 5-23a, 5-23b].

The Loss Estimates are:

(1)	1970 Expected Losses	$1901 million
(2)	2000 Baseline Losses	$2634 million
(3)	1980 Expected Losses [Table 5-23(a), (b)]	$1490.81 to $1502 million
(4)	2000 Expected Losses from new growth in Zone F [Table 5-5]	$203.4 million
(5)	Total Expected Losses, 2000 (Line #3 + Line #4)	$1694.21 to $1706 million
(6)	Expected Loss Reduction (Line #2 minus Line #5)	$939.79 to $928.0 million
(7)	Percentage Reduction	35.23% to 35.68%

Mitigation #3

Apply Mitigation #1 through 1980 and Mitigation #2 thereafter. Also, provide for removal of all structures in 2-10 year floodplains by 2000. This mitigation results in an annual expected building damage loss of $953.4 million in 2000, as shown by the following:

(1)	1970 Loss	$1901 million
(2)	2000 Baseline Loss	$2634 million
(3)	2000 Loss Under Mitigations #1 and #2	$1706 million
(4)	Loss Chargeable to Flood Zones A and B in 1980: [see Table 5-23(b)]	$740.383 million
(5)	2000 Loss, This Mitigation:	$ 953.6 million
(6)	Loss Reduction from 2000 Baseline	$1680.4 million
	% of (2)	63.8%

Mitigation #4

Apply Mitigation #1, and provide flood control facilities to protect from fifty year flood heights 167 additional cities per year between 1980-1990; and 133 additional cities per year thereafter, until all cities are so protected.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1653	981	37.2%

Mitigation #5:

Apply mitigations #1 and #4, and assume that, from 1970 - 2000, 25 cities per year provide for no net building additions in the fifty year-flood plain.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1594	1040	39.5%

Mitigation #6:

Apply Mitigations #1, and #5, and provide flood control facilities to protect from fifty-year flood heights 300 additional cities per year until all cities are so protected.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1330	1304	49.5%

Mitigation #7:

Apply mitigations 1,4,5 and beginning in 1980, floodproof to a height of 4 feet, 2% each year of all structures in the fifty-year flood plain.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1406	1228	46.6%

Mitigation #8:

Apply mitigations #1, 4, 5 and provide that, beginning in 1980, 75 additional cities per year provide for no net building additions in the fifty-year flood plain.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1570	1064	40.4%

Mitigation #9:

Apply mitigations #1, 4, 5, and, beginning in 1980, floodproof to a height of 4 feet 2% each year of all structures in the 100-year flood plain.

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2634	1329	1305	49.5%

Storm Surge

Mitigation #1:

In all 100 year storm-surge floodplains, require all new buildings (1980-2000), all building replacements (1980-2000) and essentially all others to be floodproofed after 1980 to a level of four feet. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
1177.1	477.5	699.6	59.43%

Mitigation #2: (Most Effective Mitigation)

In decreasing order of the annual storm surge damages they sustain, protect 4 surge-vulnerable counties per year, after 1980, with sea walls constructed up to the 100-year surge height. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
1177.1	334.8	842.3	71.6%

Mitigation #3:

After 1980, prohibit net new building construction on the fifty-year floodplain (permits replacement of existing structures but no net growth in building stock). Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
1177.1	912.8	264.3	22.5%

Mitigation #4:

After 1980, prohibit net new building construction on the 100-year floodplain (i.e., includes replacement of existing structures but no new growth in building stock). Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
1177.1	912.3	264.8	22.5%

Mitigation #5:

After 1980, prohibit construction of buildings with basements on the 100-year floodplain. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
1177.1	922.7	254.4	21.6%

Tsunami

Since building strengthening strategies offer little prospect of reducing tsunami-related damages to conventional buildings, the only mitigation tested is one which provides for no net increase in the residential building stock of tsunami-prone zones between 1980-2000. The large 1970-2000 increase in losses under this mitigation results from two factors: (a) continued increase in total building stock between 1970 and 1980; (b) replacement of low-valued structures by high value structures between 1980-2000. Loss estimates are:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
19.8	19.4	0.4	2.0%

Wind Hazards (Hurricane, Tornado, Severe Winds)

Mitigation #1:

Increase wind-resistance capacity of all buildings constructed after 1980 to a level representing 1.5 x current UBC requirements. The estimated losses under this mitigation are:

Hazard	2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
Hurricane	1742	1453	289	16.6%
Tornado	2058	1746	312	15.2%
Severe Wind	24.8	21.2	3.6	14.5%
Total	3824.8	3220.2	604.6	15.8%

Mitigation #2: (Most Effective Mitigation)

Increase wind-resistance capacity of all new buildings constructed after 1980 to a level representing 3.0 x current UBC requirements. The estimated losses under this mitigation are:

Hazard	2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
Hurricane	1742	1280	462	26.5%
Tornado	2058	1564	494	24.0%
Severe Wind	24.8	19.1	5.7	22.9%
Total	3824.8	2863.1	961.7	25.1%

Mitigation #3:

Population growth is halted, after 1980, in all counties where tornado strike probability is greater than 10^{-4} per year per square mile:

2000 Baseline (Million $)	2000 with Mitigation (Million $)	Loss Reduction (Million $)	(%)
2058	1813	245	11.9%

Cost Analysis

In theory, projected building damage losses from all hazards for the year 2000 may be reduced by 41.6 percent from baseline (level #1) estimates through use of the "most effective" mitigations discussed above. This level of mitigation would hold 2000 annual expected building damage losses to a value exceeding that of 1970 by only 10.6 percent, in spite of the substantial projected population increases between 1980 and 2000. As noted above, however, the "most effective" mitigations were selected without regard for either their political or economic feasibility. Accordingly, a cost analysis was performed to determine the gross relationships between the estimated costs of selected loss-reducing strategies and the annual loss-reductions expected to be produced through application of those strategies. The analysis focused on the cost and cost-to-loss reduction ratios of selected mitigations applicable to each hazard. No direct dollar costs were assigned to avoidance strategies in this study on the assumption that, at the scale of the entire nation, the bulk of the costs associated with such mitigations are simply "redistributional" in character (viz. the "costs" to property owners in one area are offset by "benefits" received by property owners in other areas). Accordingly for the purposes of this study, all avoidance strategies are considered, by definition, to be cost-effective.

Site Preparation Costs for Control of Expansive Soils Losses

The expansive soils study accepted the following values as representing the annual per capita losses associated with foundation failures, only, in areas with the indicated expansive soils rating:

High Expansivity Areas: $26.00 per capita per year
Moderate Expansivity Areas: $8.00 per capita per year
Zero and Low Expansivity Areas: $1.50 per capita per year

At an average of three persons per dwelling unit, the annual expected costs of expansive soils damage per structure in "high" expansive soils zones therefore is $78.00. Assuming a cost of $0.65 per square foot for application of soil stabilization measures and an average application of 2,000 square feet per structure site, the mitigation cost per structure is $1300. Since such mitigation measures are estimated to yield an 85% reduction in annual expected losses, the cost-effectiveness of this mitigation is as follows:

Expected annual costs without mitigation: $78.00
Expected annual costs with mitigation: $11.70
Expected annual loss reduction: $66.30
One-time mitigation cost: $1300.00
Payout period required, in years (0.0% interest): 22.2 yrs
Fifty-year annual mitigation cost at 0.0% interest: $26.00
  Ratio of annual loss reduction to annual cost: 2.55 : 1
Fifty-year annual mitigation cost at 6% interest: $82.11
  Ratio of annual loss reduction to annual cost: 0.81 : 1

In appropriate areas, control of the moisture content of soils during construction is estimated to yield a 30% reduction in annual expected losses from expansive soils while creating - in effect - only negligible additional construction costs. Thus, if the interest value of investment capital for the fifty-year repayment period is to be considered, then only site moisture control methods are cost-effective. Thus, approximately 30% of that fraction of the year 2000 annual expected losses from expansive soils which are attributable to new construction between 1980 and 2000 should be considered cost-feasible, and the total cost feasible loss reduction is only $27.9 million in the latter year.

Building Strengthening Strategies

Building strengthening strategies are defined as including: (a) floodproofing of structures in both storm surge zones and in riverine floodplains; (b) increasing the wind-resistance capacity of new buildings to a level representing either 1.5 or 3.0 x the level specified in the Uniform Building Code; (c) increasing, to the level specified for Earthquake Zone 3 in the Uniform Building Code, the capacity of new structures in seismically-active areas to withstand ground shaking.

As a first step in this analysis, we prepared a set of tables which express the proportionate increase in building costs which we expect to be associated with enforcement of selected building code mitigations. These cost factors, which were developed either through examination of relevant literature or through use of expert panels, are depicted in Tables 3-10(a) through 3-10(c). Utilizing these cost factors, the total national costs were calculated for implementation of these mitigations on the several mixes of buildings to be constructed between 1980 and 2000. [See Table 5-19].

BUILDING LOCATION	A TOTAL BUILDING VALUE, 1980 (MILLIONS OF $)	B TOTAL BUILDING VALUE, 2000 (MILLION OF $)	C BUILDING WEALTH INCREASE, 1980-2000 (MILLIONS OF $)	D MITIGATION APPLICABLE TO NEW BUILDINGS	E MITIGATION COST AS % OF BUILDING VALUE(a)	F ESTIMATED COST OF MITIGATION (MILLIONS OF $)
1. 100 YEAR RIVERINE FLOOD PLAIN	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	2FT. PROTECTION 4FT. PROTECTION	13.2% 16.6%	NOT APPLICABLE NOT APPLICABLE
2. HURRICANE AFFECTED AREAS(b)	926,502	1,680,245	753,743	1.5 x UBC 3 x UBC	2.1% 5.1%	15,828.6 38,440.9
3. STORM SURGE AFFECTED AREAS(c) ALL AREAS OF EXPOSED COUNTIES	593,278	1,061,972	468,694	2FT. PROTECTION 4FT. PROTECTION	13.2% 16.6%	61,867.6 77,803.2
4. EARTHQUAKE AFFECTED AREAS(d)	1,692,350	3,037,664	1,345,314	2 x UBC ZONE 3 ZONE 3 UBC STIS.	6.5% 2.1%	87,714.6 27,699.3
5. TORNADO AFFECTED AREAS(e)	2,383,114	4,300,491	1,917,377	1.5 x UBC 3 x UBC	2.2% 5.4%	42,813.2 103,974.8
6. SEVERE WIND AREAS(f)	2,747,291	4,924,075	2,176,784	1.5 x UBC 3 x UBC	2.1% 5.1%	45,712.5 111,015.9

(a) Tables 3-10(a) to 3-10(c), this report
(b) Hart, (1976)
(c) Lee, et. al. (1976)
(d) Excluding California, Wiggins (1976)
(e) Hart, (1976)
(f) Hart, (1976)

Table 5-19. Estimated Building Value Increases and Hazard Mitigation Costs, 1980-2000

We then selected fifty years as the effective owner-life of each building mix, and - treating all buildings constructed in each category between 1980 and 2000 as though they constituted a single cohort built at a single time - calculated the annual amortized cost for each mitigation as well as the ratio of annual loss reduction to annual fifty year repayment cost for each mitigation at three specified interest rates. [See Table 5-20].

Excluding riverine flood mitigations, which are considered elsewhere, and if a cost-feasible mitigation is defined as one which exhibits an annual loss reduction to fifty-year repayment ratio of 1/1 or greater, then only one of the proposed mitigations can be judged to be cost-effective at a 0.0% interest level for cost repayment: increasing wind resistance capacity of buildings in hurricane wind zones (both 1.5 UBC and 3.0 UBC). No mitigation could be scored as cost-feasible when fifty-year repayment of mitigation costs were calculated at 6.0% and 9.0% interest, respectively. [See Table 5-20].

BUILDING LOCATION	A	B		C	D			E			F
		ANNUAL ESTIMATED LOSS REDUCTION		REQUIRED PAYOUT PERIOD AT 0.0% INTEREST (IN YEARS)	ANNUAL FIFTY-YEAR AMORTIZED COST (12 PAYMENTS PER YEAR)			RATIO OF ANNUAL LOSS REDUCTION TO ANNUAL AMORTIZED 50 YR COST			MITIGATION
	INITIAL MITIGATION COST ($ MILLION)	BUILDING LOSSES ($ MILLION)	ALL LOSSES ($ MILLION)		0.0%	6.0%	9.0%	0.0%	6.0%	9.0%	
1. HURRICANE WIND ZONES	38,440.9	462	933.24	41.19	768.8	2428.26	3499.20	1.21/1	0.38/1	0.27/1	3 x UBC 1 x UBC
2. STORM SURGE ZONES	15,828.6	699.6	1392.2	55.86	1556.1	4914.67	7082.27	0.90/1	0.28/1	0.20/1	4FT. FLOODPROOFING 2FT. FLOODPROOFING
3. EARTHQUAKE ZONES	77,803.2 61,867.6	294.5	389.0	71.21	554.0	1749.71	2521.41	0.70/1	0.22/1	0.15/1	UBC ZONE 3 STDS.
4. TORNADO ZONES	103,974.8 42,813.2	494.0	1252.8	82.99	2079.5	6567.83	9464.62	0.60/1	0.19/1	0.13/1	3 x UBC 1.5 x UBC
5. SEVERE WINDS	111,015.9	5.7	9.2	12066.9	2220.3	7012.60	10105.56	0.004/1	0.001/1	0.0009/1	3 x UBC 1.5 x UBC

Source: Mitigation costs derived from Table 5-19, this report. Loss reductions derived from Tables 5-9, 5-10, 5-11, 5-14 and 5-22.

Table 5-20. Relationship Between National Building Strengthening Mitigation Costs and Annual Estimated Natural Hazard Loss Reductions, 2000

In view of these results, we then calculated the annual expected building damage rates that would be required of buildings constructed to "normal" standards in order to yield - at the "mitigated" level of construction - a loss-reduction-to-cost-repayment ratio of 0.75/1 or greater at a building life of fifty years and an interest rate of 6.1 percent. The results of these calculations are depicted in Tables 3-11 through 3-13. The calculations which led to these tables were based on three parameters: (1) the reduction in building damage rate expected to be experienced by buildings constructed in compliance with a specific mitigation in a specified risk category (as indicated by the baseline building damage rate); (2) the time period (fifty years) over which reduced building damage rates are expected to be experienced and loss reductions (savings) therefore accumulated; (3) the rate (6.1%) at which future loss reductions (savings) are to be discounted to account for the value at interest of current investments. The break-even damage rates which are depicted in these tables include loss reductions chargeable to non-building damage and are defined as the baseline rate which must be experienced for a specified hazard by a county level aggregation of buildings in order for total loss reduction in that county to equal total mitigation costs. Of course, a single damage rate was calculated for all wind hazards considered as a group. The rates depicted in the tables therefore are a function, not of region in which the buildings are located, but of hazard intensity, structure type, discount rate, and estimated life of building. These "break-even" damage rates then were used to identify the set of those counties of the United States in which application of each specified type of mitigation to newly-constructed buildings could be considered to be cost-feasible (viz. exhibit loss-reduction to cost ratios of 0.75/1, or higher). The resulting set therefore consists of those counties in which application of the specified mitigation to new construction between 1980 and 2000 will result in projected fifty-year building life accumulated savings in 2000 which, at a 6.1 percent discount rate, are equal to the estimated initial cost of the mitigation at the time of building construction [See Table 5-21].

Application of this procedure resulted in identification of only a comparatively small number of U.S. counties as sites where cost-feasible building strengthening mitigations may be employed to reduce annual expected losses from earthquakes, storm surge, and all wind hazards (hurricane, tornado, severe winds). [See Table 5-21]. At the "most effective" levels of mitigation discussed in the preceding section, only 104 U.S. counties qualify as candidates for the selected wind resisting mitigation at loss reduction to cost ratios of 0.75/1 or greater; only 24 for the storm surge mitigation; and only 7 non-California counties for the earthquake mitigation. [See Table 5-21]. In those counties in which loss-reduction-to-cost ratios were 1/1 or greater for the "most effective" building mitigation, estimated annual building damage losses in 1970 totaled only 11.08% of all national losses in the same year for all wind hazards, 4.82% for all non-California earthquake hazards, and 12.5% for all storm surge losses. [See Table 5-22].

HAZARD	TECHNICAL MITIGATION	NUMBER OF COUNTIES IN SPECIFIED CATEGORY OF COST-LOSS REDUCTION RATIOS					
		1-0.75 OR GREATER	1-1.00 OR GREATER	1-1.25 OR GREATER	1-1.5 OR GREATER	1-1.75 OR GREATER	1-2.0 OR GREATER
1 EARTHQUAKE	Imposition of EQ Zone #3 building code standards *1	7	2	2	2	2	2
2. STORM SURGE	Four foot elevation of structure, above flood plain level	24	17	11	8	6	2
3. STORM SURGE	Two foot elevation of structures above flood plain level	30	18	17	12	9	7
4. STORM SURGE	Flood proofing of structures to two-foot elevation above level of flood plain	36	25	18	13	10	8
5. WINDS	Escalation of building code standards to level equalling 1.5 x UBC requirements	250	229	102	76	52	28
6. WINDS	Escalation of building code standards to level equalling 3.0 x UBC requirements	104	72	28	20	16	12

*1 Does not include California counties, since these standards already are enforced there

Table 5-21. U.S. Counties, Classified by Cost-Loss Reduction Ratio Associated with Selected Natural Hazard Technology Mitigations, 1980-2000

HAZARD	MITIGATION	NUMBER OF COUNTIES WITH SAVINGS-COST RATIO OF 1:1 OR GREATER	1970 VALUE OF STRUCTURE WEALTH AT RISK (MILLIONS $)	DAMAGE RATE AT MID-POINT OF RANGE FOR COUNTIES IN CLASS	ESTIMATED ANNUAL BUILDING LOSSES, 1970 (COLUMN 3x COLUMN 4) (MILLIONS $)	ESTIMATED VALUE OF NEW CONSTRUCTION 1980-2000 (MILLIONS $)	COST OF MITIGATION, 1980-2000 (MILLIONS $)	TOTAL 50 YEAR LOSS REDUCTIONS EXPECTED FROM USE OF MITIGATION (MILLIONS $)	NET 50 YEAR SAVINGS EXPECTED (MILLIONS $)	50 YEAR SAVINGS AS PERCENT OF CUMULATIVE BUILDING VALUE (MILLIONS $)
EARTHQUAKE**	UBC ZONE #3 STANDARDS	2	307.6	0.03340	10.27	749.00	22.5	85.2	62.7	8.37%
STORM SURGE	4 FT ELEVATION OF STRUCTURES	17	4,957.9	0.01115	55.28	13,096.36	2,173.0	3,169.0	996.7	7.61%
STORM SURGE	2 FT ELEVATION OF STRUCTURES	18	5,519.4	0.01445	79.76	14,689.00	1,939.0	3,287.0	1,347.0	9.17%
STORM SURGE	2 FT FLOODPROOFING	25	23,351.3	0.00588	137.19	69,871.79	8,175.0	10,350.0	2,170.0	3.1%
WIND	1.5 UBC	229	200,100.0	0.00213	425.21	475,428.57	9,984.0	16,710.0	6,729.0	1.13%
WIND	3.0 UBC	72	54,650.0	0.00339	185.26	156,549.00	7,984.0	13,850.0	5,598.0	3.58

*Defined as Savings-Cost Ratio of 1:1, or greater
**No California counties are included

NOTE: Savings = Loss Reduction

Table 5-22. Selected Data for Counties in Which Fifty-year Loss Reduction from Use of Natural Hazard Structural Mitigations is Equal to or Less Than the Cost of Applying the Mitigation*

These values may be used to grossly estimate the proportion of the "most effective" loss reductions shown in Table 5-1 which may be judged to be "cost-feasible," and - for wind hazards - were so entered on that table.

Riverine Flood Control Mitigations

The study included a gross examination of the cost-feasibility of several major policy alternatives for reducing riverine flood losses in the year 2000. In all cases, 1980 was selected as the date for initiation of each policy, and the conditions shown in Table 5-23(a) were assumed to exist in that year.

VARIABLE	A ALL FLOOD-PRONE CITIES				B CITIES PROTECTED BY AREA FACILITIES AGAINST FIFTY-YEAR FLOODS				C CITIES NOT PROTECTED BY AREA FACILITIES AGAINST FIFTY YEAR FLOODS			
	ZONE A-D 2-50 YR. F.P.	ZONE E 50-100 YR. F.P.	ZONE F AREA OUTSIDE 100 YR. F.P.	ALL ZONES	ZONE A-D 2-50 YR. F.P.	ZONE E 50 -100 YR.F.P.	ZONE F AREA OUTSIDE 100 YR. F.P.	ALL ZONES 83.78%	ZONE A-D 2-50 YR. F.P.	ZONE E 50-100 YR.F.P.	ZONE F AREA OUTSIDE 100 YR. F.P.	ALL ZONES
1. STRUCTURES EXPOSED (1000's)	3,873.4	1,456.7	5,459.0	10,790	3,245.13	1,220.42	4,573.55	9,039.86	628.27	236.28	885.45	1,750.14
2. AVERAGE VALUE OF STRUCTURES	79,855.32	80,660.20	80,660.20	--	79,855.32	80,660.20	80,660.20	--	79,855.32	80,660.20	80,660.20	--
3. TOTAL VALUE OF BUILDINGS($MILLION)	309,311.60	117,497.71	440,324.03	867,133.34	259,140.89	98,439.32	368,903.46	726,483.67	50,170.71	19,058.39	71,420.57	140,649.67
PERCENT:	35.67%	13.55%	50.78%	100.0%	35.67%	13.55%	50.78%	100.0%	35.67%	13.55%	50.78%	100.0%
4. ANNUAL EXPECTED BUILDING DAMAGE LOSSES ($MILLION)	1,134.86	131.19	224.76	1,490.81	643.188	109.908	188.325	941.421	491.723	21.279	36.46	549.462
5. ANNUAL EXPECTED BUILDING DAMAGE RATE (%)	0.3669	0.11165	0.05105	0.1719	0.2482	0.11165	0.05105	0.1296	0.9801	0.11165	0.05105	0.3907

Table 5-23(a). Expected Building Exposures, Losses, and Building Damage Rates, 1980, by Flood Zone and Flood Protection Level of Flood-Prone Communities

FLOOD ZONE	CITIES WITHOUT AREA PROTECTION AGAINST FIFTY-YEAR FLOODS				CITIES WITH AREA PROTECTION AGAINST FIFTY-YEAR FLOODS				ALL FLOOD-PRONE CITIES			
	EXPOSED STRUCTURES (1000's)	BUILDING WEALTH ($ MILLION)	DAMAGE RATE (%)	LOSS ($MILLION)	EXPOSED STRUCTURES (1000's)	BUILDING WEALTH ($ MILLION)	DAMAGE RATE (%)	LOSS ($MILLION)	EXPOSED STRUCTURES (1000's)	BUILDING WEALTH ($ MILLION)	DAMAGE RATE (%)	LOSS ($MILLION)
ZONE A	116.167	9,068.223	2.7764	251.770	600.02	46,838.73	0.4597	215.318	--	--	--	467.09
ZONE B	129.109	10,210.140	1.1980	122.317	666.87	52,881.83	0.2855	150.978	--	--	--	273.30
ZONE C	172.146	13,885.331	0.5819	80.799	889.17	71,720.63	0.2139	153.410	--	--	--	234.21
ZONE D	210.847	17,006.961	0.2168	36.871	1,089.07	87,844.60	0.14088	123.756	--	--	--	160.63
ZONE E	236.280	19,005.390	0.11165	21.220	1,220.42	98,439.32	0.11165	109.908	1,456.7	117,497.71	0.11165	131.19
ZONE F	885.450	71,420.57	0.05105	36.460	4,573.55	368,903.46	0.0515	188.325	5,459	440,324.03	0.05105	224.76
$\sum$ ZONE A-C	417.42	33,163.69	1.3716	454.886	2,156.06	171,296.29	0.3052	519.706	--	--	--	974.59
$\sum$ ZONE A-D	628.27	50,170.71	0.9801	491.757	3,245.13	259,140.89	0.2483	643.462	3,873.4	309,311.6	0.3669	1,134.86
$\sum$ ZONE A-E	864.69	69,176.05	0.7416	512.977	4,466.31	357,580.21	0.2107	753.37	5,331.0	--	--	1,266.35
$\sum$ ZONE A-F	1,750.14	140,596.615	0.3908	549.437	9,039.86	726,483.67	0.1296	941.695	10,790	--	--	1,491.13

Table 5-23(b). Expected Building Wealth Exposures, Damage Rates, and Losses in Individual Flood Zones, 1980

These baseline conditions were developed through application of the following assumptions and procedures to major data outputs from the computer-based riverine flood model utilized in the study:

(a) The proportion of U.S. structures, building wealth, and population located in flood-prone cities in the period 1970 to 2000 was assumed to be as shown in Table 5-24. The values presented in Row 6 (number of cities with area

VARIABLE	1970	1980	2000
(1) NUMBER OF CITIES[a]	5539	--	6,455
(2) NUMBER OF BUILDINGS (1000's)[b]	9108	10,790	15,729
(3) BUILDING WEALTH ($ MILLION)[c]	731,977	867,153	1,264,083
(4) STRUCTURES PER CITY	1,644.0	1,846.0	2,116.0
(5) BUILDING WEALTH PER CITY	132.15	--	195.83
(6) NUMBER OF CITIES WITH AREA PROTECTION AGAINST FIFTY-YEAR FLOODS	2,037[d]	4,037[e]	--
(7) PERCENT OF ALL STRUCTURES PROVIDED WITH AREA PROTECTION AGAINST FIFTY-YEAR FLOODS[f]	51.64%	83.78%	--
(8) POPULATION: TOTAL (1000's)[g]	24,712	29,292	42,769
PER CITY			

Source: (a) Lee. et. al., (1976), Tables 2-7, 2-21
(b) Lee, et. al., (1976), Table 2-27
(c) Tables 5-3, 5-4, 5-23(a), 5-23(b), 5-25
(d) Lee, et. al., (1976), Table 2-23
(e) Lee, et. al., (1976), Table 2-26, Run III
(f) Calculated from data presented in Tables 5-3, 5-4, 5-23, 5-25
(g) Lee, et. al., (1976), Table 2-27

Table 5-24. Selected Attributes of Cities in Flood Model, 1970-2000

structural protection against fifty-year floods) represent assumptions built into the computer model for the purpose of providing 1980 base values against which the impacts of future alternative loss-reducing strategies might be tested. The values presented in Row 7 (percentage of all buildings located in cities provided with area protection against fifty-year floods) were calculated through use of data presented in Tables 5-3, 5-4, and 5-25, and through application of the following formulae to determine the values of P and W_2 in 1970 and 1980:

$$\frac{BDR_1(W_1) - L}{BDR_1 - BDR_2} = W_2$$

and:

$$\frac{W_2}{W_1} = P$$

where:

P = proportion of building wealth in protected communities
W_2 = building wealth in protected communities
L = annual expected loss, Zones A through D
BDR_1 = building damage rate in unprotected communities
BDR_2 = building damage rate in protected communities
W_1 = total building wealth in Zones A through D of all floodprone communities

(b) As shown in Table 5-25 (Row 4g) building damage rates for Zones F, E, and the portion of the floodplain represented by Zones A through D were determined for 1970 (actual), 1980 (Run III), 2000 (Run III), and 1970 (Run III). Computer model Run III values assume only one mitigation, provision of area facilities to protect communities against fifty-year floods with 2000 representing complete protection. The 1970 Run represents a condition in which no fifty-year protection has been extended to any city. Thus, the value of BDR_1 was set at 0.9801 and the value of BDR_2 at 0.2482.

(c) To determine the costs and payoffs associated with alternative mitigations, building damage rates for Zones A through D were needed for two conditions:

Condition #1: No area protection provided against fifty-year floods
Condition #2: Area protection provided against fifty-year floods

Utilizing computer model outputs, these rates were determined to be as shown in Table 5-23(b) and 5-25. The rates were determined as follows:

VARIABLE	1970[a] ACTUAL	1980[b]	2000[c]	1970, RUN 1[d], NO FLOOD PROTECTION
1. NUMBER OF EXPOSED BUILDINGS (1000's)	9108	10,790	15,729	9,108
2. BUILDING WEALTH: ($MILLION)				
a. FLOOD ZONE A	47,992.50	56,852.52	82,878.4	47,992.50
b. FLOOD ZONE B	54,020.61	64,000.70	93,292.5	54,020.61
c. FLOOD ZONE C	73,465.31	87,032.36	126,870.4	73,465.31
d. FLOOD ZONE D	89,992.59	106,616.65	155,416.1	89,992.59
e. FLOOD ZONE E	99,179.78	117,489.65	171,273.9	99,179.78
f. FLOOD ZONE F	367,326.55	435,161.78	634,352.0	367,326.55
g. FLOOD ZONE A-D	265,471.01	314,502.23	458,457.4	265,471.01
3. BUILDING DAMAGE LOSSES ($MILLION)				
a. FLOOD ZONE A	758.3	475.061	380.98	1,332.464
b. FLOOD ZONE B	392.6	277.492	266.39	647.167
c. FLOOD ZONE C	287.9	238.074	271.33	427.495
d. FLOOD ZONE D	159.8	163.311	218.95	195.104
e. FLOOD ZONE E	111.8	129.885	191.23	110.734
f. FLOOD ZONE F	190.6	218.614	328.84	187.520
g. FLOOD ZONES A-D	1,598.6	1,153.938	1,137.65	2602.230
h. FLOOD ZONES A-F	1,901.0	1,502.437	1,657.72	2,900.484
4. BUILDING DAMAGE RATES (%)				
a. FLOOD ZONE A	1.5800	0.8356	0.4597	2.7764
b. FLOOD ZONE B	0.7268	0.4336	0.2855	1.1980
c. FLOOD ZONE C	0.3919	0.2736	0.2139	0.5819
d. FLOOD ZONE D	0.1776	0.1532	0.14088	0.2168
e. FLOOD ZONE E	0.1127	0.1106	0.11165	0.1116
f. FLOOD ZONE F	0.05190	0.0502	0.05105	0.0510
g. FLOOD ZONES A-D	0.6022	0.3669	0.24815	0.9802

Source: (a) Table 5-3
(b) Table 5-4
(c) Building count, line #1, derived from Lee, et.al. (1976), Table 2-27 Building wealth distribution calculated from average building values cited in Table 5-3, and from data in Table 3-3, this report. Building damage rates for zones E and F set at average of rates in 1980 and 2000. Rate in line 4g determined arithmetically using total loss ($1653 million) reported by Lee, et.al. (1976), Table 2-28. Damage rates for zones A through D calculated on basis of data presented for 1970 and 1980, this table, and on basis of percent of structures protected against fifty-year floods [see Table 5-24].

Table 5-25. Building Exposures, Losses, and Damage Rates Under Selected Conditions, by Flood Zone, 1970-2000.

(1) for both sets of communities rates for flood Zones F and E were set at the average of the rates shown for these zones in Tables 5-3 and 5-4, or 0.05105% and 0.11165%, respectively;

(2) the 1970-80 reduction in damage rates in each of Zones A through D for each 1% of additional structures provided with fifty-year flood protection was determined;

(3) these values then were applied to the percent increase in structure protection between 1980 and 2000 in Computer Model Run III to determine individual flood zone rates.

These values then were taken as being the building damage rates for Zones A-F under a condition where all structures have been provided with area protection against fifty year floods. Utilizing these values, the Table 5-24 value in Row 7 for 1970 (actual), and the data shown in Table 5-3, the building damage rates were determined arithmetically for Flood Zones A - D where no area protection is provided against fifty year floods. The full range of these rates is displayed in Table 5-25.

(d) For baseline purposes, 1980 riverine flood exposures, losses and building damage rates in floodprone cities were assumed to be as shown in Table 5-23. Column A values were derived from the following procedure:

(1) The total number of exposed structures shown in Table 5-24 for 1980 was entered and distributed among the several zones in the proportions shown in Table 3-2;

(2) The number allocated to Zones A-D then was depressed by 64,000 to account for the anticipated 1970-80 diversion of population growth away from the fifty-year floodplains as a result of on-going floodplain zoning activities during that period [Lee, et. al.,(1976), Table 2-26, 2-27], and this number was added to Zone F;

(3) The resulting building counts then were distributed to "protected" and "unprotected" communities in accordance with the values presented in

Table 5-24, Row 7. Building damage rates and average structure values were taken from Tables 5-25 and 5-3, respectively.

Cost factors for floodproofing and elevating structures were taken from Table 3-10(c). Property purchase costs were calculated from the building values presented in Table 5-23 to which were applied a land purchase cost factor of 6.95% [Lee, et. al., 1976, page 41] and a factor of 21.6% to account for conveyance, demolition, and site restoration costs [Johnson, 1978, page 51]. Costs of area flood protection were derived by first setting 1936-76 U.S. expenditures for area flood control works at $10.5 billion [Miller, 1978]. This amount then was converted into 1970 "constant" dollars through the following procedure: a) the total $10.5 billion dollar investment between 1936 and 1976 was allocated equally to each of the several years in that period; (b) the fraction expended between 1936 and 1970 then was calculated and allocated to the years in each of the three decades, 1940-1950, 1950-1960, 1960-1970; (c) the investments in each of these three decades then were treated as though they had been made at the mid-points of each of these decades, and these investments were converted into 1970-constant dollars through the use of an index which treated the purchasing power of the dollar in 1970 as having a value of 1.00 and the purchasing power of dollars in the other decades as having proportionately higher index values based on their real purchasing power in 1970 dollars [See Table 500, Statistical Abstract of the United States, 1968]. Based on this procedure, the accumulated 1936 to 1969 investment in U.S. flood control facilities was found to total $13,523.4 million 1970 dollars. Based on the assumption that 2037 cities had been protected from fifty-year floods in 1970 as a result of this investment [See Table 5-24], the cost per city protected was set at $6.638 million ($13,523.4 million ÷ 2037).

Utilizing the data discussed above, the cost feasibility of alternative riverine flood mitigations was found to be as shown below. In the calculations, all annual repayment costs were calculated on the basis of equal monthly payments x 12, and annual estimated <u>total</u> loss reductions were based on the storm surge ratio of total losses to building losses in the appropriate year, as depicted in Tables 4-1 and 4-2. For 1970 this ratio was 1.45:1, while for 2000, it was 1.99:1.

Area Protection Against Fifty Year Floods

Without considering the annual costs of maintenance and operation, the cost-feasibility of pre-1970 investments in flood control projects was estimated as follows:

Initial Mitigation Costs (IMC)	$13,523.4 million
Annual Estimated Building Loss Reductions (BLR), 1970 [see Table 5-25, Column D-Column A]	$ 999.5 million
Annual Estimated Total Loss Reductions (TLR), 1970	$ 1,449.28 million
Payout Period, in Years (IMC ÷ TLR)	9.33 years
Fifty-Year Annual Repayment Cost (0.0%)	$ 270.47 million
Ratio of Annual Loss Reduction (ALR) to Annual Repayment Cost (ARC)	5.36:1
Fifty-Year Annual Repayment Cost (6.0%)	$ 854.23 million
Ratio of ALR to ARC	1.7:1
Fifty-Year Annual Repayment Cost (9.0%)	$ 1,231.01 million
Ratio of ALR to ARC	1.18:1

Utilizing loss projections from the riverine flood model and estimated flood protection costs of $6.638 million per urban community, the cost-feasibility of 1970-2000 investments in area facilities to protect against fifty year floods was estimated, as follows:

Number of Cities to be Protected [Table 5-24]	4,418
Initial Mitigation Cost	$29,326.7 million
Annual Estimated BLR, 2000 [See Table 5-25, Column C, Bldg. Wealth (Zones A-D) x Column A Bldg Damage Rate (Zones A-D) minus Column C Loss (Zones A-D)]	$ 1,628.20 million
Annual Estimated TLR, 2000	$ 3,240.12 million
Payout Period, in Years	9.05 years
Fifty-Year Annual Repayment Cost (0.0%)	$ 586.53 million
Ratio of ALR to ARC	5.5:1
Fifty-Year Annual Repayment Cost (6.0%)	$ 1,852.53 million
Ratio of ALR to ARC	1.75:1

Fifty-Year Annual Repayment Cost (9.0%) $ 2,669.56 million
Ratio of ALR to ARC 1.21:1

Thus, based on these crude calculations, both pre-1970 and 1970-2000 investments in area systems to protect against fifty-year floods may be considered to be cost-feasible at all three interest rates employed, 0.0%, 6.0%, and 9.0%. At the 6.0% interest level, pre-1970 investments in flood control works produced net savings (annual total loss reduction minus 50 year ARC) which totalled approximately $595.05 million per year, or a net annual reduction of approximately 20.5% for the projected loss ($2900.5 million) that would have occurred without the investment. Of course, to the extent that these investment stimulated construction in fifty-year floodplains that would not otherwise have taken place, and to the extent that these investments also stimulated additions to the stock of flood-damageable urban infra-structure (streets, utility lines, sidewalks, etc.) these net savings may, in fact, be reduced to values approaching zero. Since losses to urban infrastructure were not estimated in this study, no offsetting reduction has been applied to this "net savings" value.

To determine the cost-feasibility of avoidance and area flood protection strategies between 1980 and 2000, the data depicted in Table 5-26 were utilized.

	FLOOD ZONE			
	ZONE A-D	ZONE E	ZONE F	ALL ZONES
1. BUILDING WEALTH (1980 DISTRIBUTION)	450,898.5	171,283.3	641,901.5	1,264,083.3
2. 1980 BUILDING DAMAGE RATE (%)	.3669	.11165	.05105	--
3. LOSSES UNDER 1980 CONDITIONS ($ MILLIONS)	1,654.35	191.24	327.69	2,173.3
4. BUILDING DAMAGE RATE WITH 50 YEAR FLOOD PROTECTION EXTENDED TO ALL AREAS	.2482	.11165	.05105	--
5. LOSSES UNDER MITIGATION CONDITION	1,119.13	191.24	327.69	1,638.08
REDUCTION:	--	--	--	(535.22)
6. BUILDING WEALTH UNDER AVOIDANCE STRATEGY	309,311.6	117,497.7	837,274	1,264,083.3
7. 1980 BUILDING DAMAGE RATE (%)	.3669	.11165	.05105	--
8. LOSSES UNDER AVOIDANCE MITIGATION	1,134.86	131.19	427.43	1,693.48
REDUCTION:	--	--	--	(479.82)

Source: Data derived from Tables 5-23(a), 5-25.

Table 5-26. Riverine Flood Building Damage Losses, 2000, Under Two Mitigations

Assuming that avoidance strategies result in no direct costs, a shift of all 1980-2000 building growth to Zone F will produce a net total loss reduction per year of $954.84 million ($479.82 million x 1.99). In contrast, an area flood protection strategy will produce a gross annual loss reduction of $1,065.09 million ($535.22 million x 1.99). Use of such a strategy would require the flood protection of 2418 communities [See Table 5-24, Rows 1 and 6] at a cost of $6.638 million, each. Thus, the net total annual savings from area flood protection between 1980-2000 is as follows:

Initial Mitigation Cost (2418 x $6.638 million)	$16,050.64 million
Annual Fifty Year Repayment Cost (6.0%)	$ 1,013.90 million
Annual Loss Reduction	$ 1,065.09 million
Net Loss Reduction	$ 51.19 million

Although such a strategy clearly is cost feasible, much larger net savings are achievable through application of a strategy which prohibits net new growth in the 100-year floodplains. Also, if an avoidance strategy is adopted, then the provision of flood protection facilities to 1980 structures in Zones A-D will not be cost feasible. Such protection would reduce A-D losses in unprotected communities from $491.757 million per year for an annual loss reduction of only $367.183 million (calculated from data in Table 5-23(b))

Building Removal Strategies

To determine the cost-feasibility of building removal strategies between 1980 and 2000, the data depicted in Table 5-27 were utilized. As shown there, this strategy is effective only at the 0.0% interest level in Flood Zone A. At 6% it is cost-feasible in no flood zone.

Of course, if the potential recreational and public-use benefits were calculated for the public open space liberated as a result of this kind of strategy, then the policy might be considered to be cost-feasible in at least Flood Zone A of "unprotected" communities. In any event, no net savings could be shown for this mitigation.

	ZONE A	ZONE B	ZONE C
1. 1980 BUILDING VALUE ($ MILLION)	9,068.223	10,210.140	13,885.331
2. REMOVAL COST ($ MILLION)	11,657.20	13,125.14	17,849.59
3. ANNUAL BUILDING DAMAGE LOSS ($ MILLION)	251.770	122.317	80.799
4. ANNUAL LOSS REDUCTION (ALR) ($ MILLION)	501.02	243.41	160.79
5. PAYOUT PERIOD, IN YEARS	23.27	53.92	111.01
6. FIFTY-YEAR ANNUAL REPAYMENT COST (ARC) AT 0.0% ($ MILLION)	233.14	262.50	356.99
7. RATIO OF ANNUAL LOSS REDUCTION TO ANNUAL REPAYMENT COST	2.15:1	0.93:1	0.45:1
8. FIFTY-YEAR ARC, 6.0%	736.37	NC	NC
9. RATIO OF ALR TO ARC	0.68:1	NC	NC

Source: Table 5-23(b). Removal costs calculated at 1.2855 x building value. See Johnson [1978], page 51 and Lee, et al [1976], page 41.

Table 5-27. Cost Feasibility of Building Removal Strategies in Flood Zones A-C of Flood Prone Cities Not Provided with Area Protection Against Fifty-year Floods

Floodproofing of Structures

The final riverine flood cost-feasibility test was applied to a joint strategy involving both structure floodproofing and provision of area protection against fifty-year floods. Data utilized in the analysis are depicted in Table 5-28.

As shown there, the mitigation involves the four-foot floodproofing of all structures in Flood Zones A-D under a condition where all communities have been provided with area protection against fifty-year floods. Also, the computer run assumed that only 40% of all buildings were floodproofed by 2000 [Lee, et.al., (1976), Table 2-26]. Costs of floodproofing were fixed at 16.5% of building value [See Table 3- 13] and this cost was applied to 40% of the building value (Zones A-D) shown in Table 5-28.

FLOOD ZONES	COMPUTER MODEL CONDITION		BUILDING DAMAGE RATES AND LOSSES			
			AREA PROTECTION, ONLY		4FT FLOODING AT ZONE A-D BUILDING PLUS AREA PROTECTION	
	STRUCTURES EXPOSED A	BUILDING WEALTH B	DAMAGE RATE (%) C	LOSS ($ MILLION) D	DAMAGE RATE (%) E	LOSS ($ MILLION) F
ZONE F	7,722.5	622,898.4	0.05105	317.99	0.05105	317.99
ZONE E	2,085.1	168,184.6	0.11165	187.78	0.11165	187.78
ZONES A-D	5,637.4	450,176.4	0.2482	1,117.34	0.2000	900.23
ALL ZONES	15,445	N.C.	--	1,623.11	--	1,406.00

Source: Column A values taken from Lee., et.al. (1976), Table 2-27, Runs VII and VIII (2000), and from zonal distributions shown in Table 3-2, this report.

Column B values derived form application of average building values (Table 5-3) to Column A values.

Column C values derived from Table 5-25, column C.

Column E zone F and E values derived from Column C. Zones A-D value calculated from data in Column F.

Column F value for all zones derived from Lee et.al (1976), Table 2-28, Run VI (2000) and other values calculated

Table 5-28. Baseline Data for Building Floodproofing Cost Feasibility Analysis

The cost-feasibility of this mitigation was found to be as follows:

Initial Mitigation Cost	$29,891.71 million
Annual Estimated Building Loss Reduction	$ 247.00 million
Annual Total Loss Reduction	$ 491.53 million
Payout Period Required, in Years (0.0%)	60.81 years
Fifty Year Annual Repayment Cost (0.0%)	$ 597.83 million
Ratio of ALR to ARC	0.83:1

Storm Surge Mitigations

As noted above (Building Strengthening Strategies), a break-even analysis was conducted to identify those counties in which the application of various building strengthening strategies to new construction between 1980 and 2000 would produce loss-reduction-to-cost ratios of 0.75 to 1.00, or greater. Less than half of the U.S. counties exposed to storm surge events met the test, and only 25 exhibited loss-reduction-to-cost ratios of 1-to-1 or higher for two-foot floodproofing of all structures [See Tables 5-21 and 5-23]. The latter counties represented only 31.07% of 1970 building damage losses from storm surge ($137.19 million ÷ $441.59 million).

However, the test employed was one which assumed that all new structures added to the study counties would be subjected to the mitigation, and not simply those which were located within the surge-vulnerable portions of the county [See discussion in Chapter Three, "Cost Feasibility Analysis"].

Accordingly, Table 5-29 was developed. As indicated there, only 25.28% of the 1970 building wealth of surge-exposed counties was located at an "adjusted" elevation of 20' or less above mean sea level. It was that level which was defined in the model as being the surge-damage area [See Chapter Three]. In view of this

ADJUSTED ELEVATION ABOVE MSL (FEET)	POPULATION		BUILDING WEALTH		ANNUAL EXPECTED BLD. DAM. LOSSES ($ MILLION)	BUILDING DAMAGE RATE (%)
	N	%	($ MILLION)	%		
1. 0-5 MSL	4,502,369.75	45.295	47,410.39	45.295	--	--
2. 5-10 MSL	1,363,285.00	13.715	14,355.52	13.715	--	--
3. 10-15 MSL	2,224,694	22.381	23,426.25	22.381	--	--
4. 15-20 MSL	1,849,753	18.609	19,478.09	18.609	--	--
5. 0-20 MSL	9,940,101	100.0	104,670.25	100.000	441.591	0.4219
6. OTHER AREAS OF PARENT COUNTIES	29,447,146	--	309,328.48	--	NONE	NONE
7. ALL AREAS OF EXPOSED COUNTIES	39,387,247	--	413,998.75	--	441.591	0.1067

Source: Calculated from data presented in Lee, et.al. (1976), Table 3-2, Figure 3-9, and Appendix A

Table 5-29. Distribution of Population and Building Wealth in Storm Surge Zones, 1970, by Adjusted Elevation Above Mean Sea Level fact, it seems clear that the gross-grained break-even analysis probably understates the cost-feasible building mitigations which may be applied to structures within storm surge hazard areas.

Accordingly, the data presented below were developed. These data are based on the annual expected building damage losses generated by computer storm surge mitigation #1 [Lee, et al, (1976), Table 3-3], which assumed a near-complete 4-foot floodproofing of all hazard zone structures between 1980 and 2000. For the purpose of the analysis, it was assumed that 4-foot floodproofing costs (16.5% of building value) should be applied to the entire building wealth of the storm surge zone [See Table 5-29]. The results of the analysis are as follows:

Initial Mitigation Cost ($278,999.76 million x 16.6)	$46,313.96 million
Annual Fifty-Year Repayment Cost, 0.0% (ARC)	$ 926.28 million
Annual Building Damage Loss Reduction	$ 699.60 million
Annual Total Loss Reduction (TLR) ($699.60 x 1.99)	$ 1,392.20 million
Ratio of Annual Total Loss Reduction to ARC	1.50:1

Although this level of payout-performance is not acceptable at interest levels of 6.0 and 9.0%, it does suggest that such mitigations would be cost-feasible at these higher interest rates if the mitigation was applied to selected flood-frequency and flood height-classified sections of the hazard zone. Although project constraints prevented us from performing such an analysis, it seems not unreasonable to assume that approximately one-half of the mitigated loss reduction ($349.8 million) would be cost-feasible at the 6.0% interest level and this value therefore was entered on Table 5-1.

Although sea-wall construction was the "most effective" mitigation shown for storm surge, no cost analysis was performed for this mitigation. It is known that costs of such construction have ranged from $100 to $500 per foot of shoreline protected [U.S. Corps of Engineers, 1971], but project constraints prevented us from determining the cost-range appropriate for each of the counties in the exposed area, and the approximate miles of wall required. The difficulties associated with determination of the latter are suggested in Table 5-30 which depicts the miles of general and tidal shoreline in each of the relevant states, ranked in terms of their annual expected storm surge building damage rates for the 0-20' adjusted mean sea level portion of their surge-exposed coastal counties.

STATE	A ANNUAL EXPECTED BLDG. DAMAGE RATE (%) IN AREAS 0-20' MSL, ADJUSTED	B MILES OF SHORELINE	
		GENERAL COASTAL	TIDAL SHORELINE
1. MISSISSIPPI	1.4290	44	359
2. GEORGIA	1.3928	100	2,344
3. FLORIDA	0.8595	1,350	8,426
4. ALABAMA	0.7280	53	607
5. LOUISIANA	0.5632	397	7,721
6. RHODE ISLAND	0.5352	40	384
7. NORTH CAROLINA	0.4072	301	3,375
8. TEXAS	0.3797	367	3,359
9. MASSACHUSETTS	0.3620	192	1,519
10. CONNECTICUT	0.3392	--	618
11. SOUTH CAROLINA	0.2474	187	2,876
12. MAINE	0.2227	228	3,478
13. DELAWARE	0.1993	28	381
14. NEW YORK	0.1883	127	1,850
15. VIRGINIA	0.1546	112	3,315
16. NEW JERSEY	0.1379	130	1,792
17. MARYLAND	0.1168	31	3,190
18. NEW HAMPSHIRE	0.0253	13	131
TOTALS		3,700	48,069

Source: Column A Calculated from Data Presented in Lee, et.al. (1976)
Column B Data Derived from : Dept. of Commerce, Environmental Sciences Administration, Coastline of the United States (April 1, 1961)

Table 5-30. Miles of General and Tidal Shoreline in Storm Surge-prone Counties of the United States

As in the case of riverine flooding, however, it seems likely that the largest net savings are to be derived from use of avoidance strategies. Thus, computer mitigation Run #3 [Lee, et.al. (1976), Table 3-3] reveals that prohibitions on net new exposures in the fifty-year storm surge floodplain would reduce baseline 2000 losses to $912.8 million, for an annual loss reduction of $264.3 million all of which may be considered net savings. Even if sea-wall construction costs only \$300 per linear foot, and even if only 3000 miles of coastline require such walls in order to produce the loss reductions shown by the computer model, the net annual loss reduction from use of sea-walls would be as follows:

Initial Mitigation Cost (3000 miles @ \$1.584 million)	\$4,752.0 million
Fifty-year Annual Repayment Cost (6.0%)	\$ 300.17 million
Annual Loss Reduction (\$1177.1 million minus \$334.8 million)	\$ 842.30 million
Net Savings	\$ 542.13 million

From these net savings, appropriate analysis would require offsetting costs to account for damage to the coastal ecosystem [White, 1976], including the steepening and reduction of beach width produced by modified wave action [Pilkey, Pilkey, and Turner, 1975]. Moreover, the above-simplified calculation unquestionably understates the costs involved in sea wall construction per mile of real coastline protected. Thus, in nearly one-half of the hurricane and shoreline protection studies completed by the Corps of Engineers since 1955, the Corps found the proposed project to be economically unfeasible.

Thus, avoidance strategies have been entered in Table 5-1 as those producing the highest net loss reductions per year.

Economic Payoffs from Major Mitigation Groups

As noted in the opening section of this chapter, annual loss reductions in 2000 were estimated for each hazard for each of three mitigations: (1) that mitigation which produced the largest gross annual reduction in building damage losses (Most Effective Mitigation); (2) that "cost-feasible" mitigation which produced the largest gross annual reduction in building damage losses; (3) that mitigation which produced the largest net annual loss reduction.

A "cost-feasible" mitigation is defined as one whose annual fifty-year amortized cost at 6.0% interest is at least equal to the annual loss reduction secured through use of the mitigation. The mitigations which, for each hazard, were judged to be either the "most effective" or the "most effective, cost-feasible" were depicted in Figures 5-1 and 5-2.

When net savings are defined as the difference between the annual loss reductions which are achievable through use of a mitigation and the annual amortized fifty-year costs of the mitigation, at 6.0%, then the specific mitigations which were judged in this study to be those offering the highest annual net savings are those depicted in Figure 5-4. As noted earlier, all avoidance mitigations were assumed to involve zero net national-level costs.

HAZARD	MITIGATION
1. HURRICANE WINDS 2. TORNADO 3. SEVERE WINDS	FOR NEW BUILDINGS CONSTRUCTED AFTER 1979 IN 229 COST-FEASIBLE COUNTIES [TABLE 5-21], INCREASE DESIGNED WIND RESISTANCE CAPABILITY TO LEVEL EQUALLING 1.5x THE LEVEL SPECIFIED IN THE UNIFORM BUILDING CODE. IN THE COST-FEASIBLE SUBSET NUMBERING 72 OF THESE SAME COUNTIES [TABLE 5-21], INCREASE DESIGNED WIND RESISTANCE CAPABILITY TO LEVEL EQUALLING 3.0x THE LEVEL SPECIFIED IN THE UNIFORM BUILDING CODE.
4. EARTHQUAKE	CONTINUE APPLICATION OF UBC EARTHQUAKE ZONE #3 LATERAL FORCE REQUIREMENTS IN ALL CALIFORNIA COUNTIES AND EXTEND REQUIREMENTS TO THE TWO NON-CALIFORNIA COUNTIES IN WHICH THIS MITIGATION IS COST-FEASIBLE [TABLE 5-21]
5. EXPANSIVE SOILS	APPLY CONSTRUCTION SITE MOISTURE CONTROL TECHNIQUES IN AREAS WHERE THE BUILDING SEASON IS MARKED BY WIDE VARIABILITY IN RAINFALL LEVELS.
6. LANDSLIDE	REQUIRE SOILS TESTING AND IMPROVED SITE-GRADING TECHNIQUES IN ALL LANDSLIDE-PRONE AREAS. APPLY MITIGATION TO NEW CONSTRUCTION AFTER 1979.
7. TSUNAMI	PERMIT ZERO NET RESIDENTIAL GROWTH IN TSUNAMI-PRONE AREAS AFTER 1979
8. STORM SURGE	AFTER 1979, PROHIBIT NET NEW BUILDING CONSTRUCTION ON THE FIFTY-YEAR FLOODPLAIN
9. RIVERINE FLOODING	AFTER 1979, PROHIBIT NET NEW CONSTRUCTION IN 100 YEAR RIVERINE FLOODPLAINS.

Figure 5-4. Mitigations Exhibiting Highest Net Savings, by Hazard

Since both project constraints and the gross quality of some hazard or vulnerability data did not permit the investigators to perform a hazard-by-hazard, building mix-by-building mix, and mitigation-by-mitigation marginal analysis of costs in relation to loss reductions, the terms "net savings" and "highest net savings" mitigation, should be viewed accordingly.

They are intended not to provide the finest-grained perspective of what is to be gained and lost, economically, through any particular mix of mitigations but to fix the gross boundaries within which the probable costs and payoffs of technologically-feasible mitigations may be judged at the national level.

When so viewed, and when annual expected hazard costs are defined as including both annual expected losses associated with hazard exposures and the annual amortized costs of mitigating those hazards, then a range of policy-useful natural hazard cost data for 2000 are as shown in Table 5-31.

HAZARD	ALTERNATIVE NO. 1 (DO NOTHING AFTER 1980)		ALTERNATIVE NO. 2 (APPLY "MOST EFFECTIVE" MITIGATION)			ALTERNATIVE NO. 3 (APPLY "HIGHEST NET SAVINGS MITIGATION)		
	A BLDG. DAMAGE LOSS ($MILL.)	B TOTAL DAMAGE LOSS ($MILL.)	C TOTAL DAMAGE LOSS ($MILL.)	D ANNUAL MIT. COST @ 6.0% ($MILL.)	E TOTAL HAZARD COST ($MILL.)	F TOTAL DAMAGE LOSS ($MILL.)	G ANNUAL MIT. COST @ 6.0% ($MILL.)	H TOTAL HAZARD COST ($MILL.)
1. HURRICANE[a]	2,554.46	5,875.3	4,364.3	2,428.3	6,792.6			
2. TORNADO[a]	1,267.2	2,914.6	2,215.2	3,748.8	5,964.0	7,869.76	927.34	8,797.1
3. SEVERE WIND[a]	3.14	7.2	5.6	835.7	841.3			
4. EARTHQUAKE	1,177.	1,553.7	1,430.9	2,549.5	3,980.4	1,550.1	1.42	1,551.5
5. EXPANSIVE SOILS	997.1	997.1	760.1	292.6	1,052.7	969.2	0	969.2
6. LANDSLIDE	871.2	871.2	349.4	0	349.4	349.4	0	349.4
7. TSUNAMI	19.8	40.4	39.6	0	39.6	39.6	0	39.6
8. STORM SURGE	1,176.0	2,342.9	950.23	2,925.6	3,875.8	1,816.5	0	1,816.5
9. RIVERINE FLOOD								
OPTION A	2,634.	5,241.7	1,897.3	12,915.5	14,812.8	3,371.5	0	3,371.5
OPTION B	2,634.	5,241.7	2,465.4	2,094.9	4,560.3	--	--	--
TOTALS	10,699.9	19,844.1	(A) 12,012.61 (B) 12,580.71	(A) 25,696. (B) 14,875.4	(A) 37,708.6 (B) 27,456.1	15,966.06	928.76	16,894.8

a. See discussion in text re: these values.

Table 5-31. Net Annual Expected Natural Hazard Costs in 2000

Data presented in Table 5-31 were derived from Table 5-1, 5-19, 5-20, and from the cost and loss analysis discussions presented above. However, in the table, the following assumptions were made: (1) all building wealth exposed to hurricane winds also is exposed to tornado and severe winds; (2) all building wealth exposed to tornado also is exposed to severe wind; (3) severe wind exposures, for purposes of cost analysis, are limited to areas not also prone to either hurricane winds or tornado; (4) annual expected losses, loss reductions, and mitigation costs may be apportioned to the aforementioned subsets of counties in proportion to their projected building wealth increase between 1980-2000. These assumptions therefore alter the cost analysis presented in Table 5-19, as shown in Table 5-31. Also, our inability to fix a cost for seawall construction led us to specify four-foot floodproofing of all structures in surge-prone zones (0-20' M.S.L., adjusted) as the "most effective" mitigation for this hazard for purposes of Table 5- 31.

Further, in the case of riverine flooding, we have provided two optional "most effective" mitigations: Option A involves the removal of all structures in Flood Zones A-C of all floodprone communities while Option B involves the removal of such structures only from these same zones in floodprone communities which have not been provided with area flood control facilities sufficient to protect them against fifty-year floods.

As shown in Table 5-31, the zealous application of the "most effective" mitigations to all hazards would escalate net annual expected hazard costs in 2000 to a level ranging from 38 to 90% beyond the level that would be experienced if the nation adopts a complete "do nothing" policy in 1980 and adheres to such a policy through the year 2000.

In contrast to the excalation in net hazard costs that result from use of "most effective" mitigations, the use of the mitigations which yield the "highest net savings" will reduce net hazard costs in 2000 by approximately 14.9% [See Table 5-31].

The "highest net savings" entry in Table 5-31 for wind hazards was derived by calculating the annual amortized costs of the mitigation at 6.0% from the data given in Tables 5-19 and 5-22. This value, plus 1/50th of the net fifty year savings shown for the mitigation in Table 5-22, then was subtracted from the baseline loss estimate to secure the loss level associated with the mitigation. An identical procedure was utilized to estimate earthquake losses under this mitigation.

Social Payoffs for Major Mitigation Groups

In the above discussion alternative mitigation strategies have been examined primarily from the perspective of direct economic gains and losses. Thus, each of the five categories of annual expected loss estimates for the year 2000 [See Table 5-1], as well as the annual expected net hazard costs shown in Table 5-31, have considered only the economic costs associated with expected damage to buildings and their contents, supplier losses, income loss, and the capital costs associated with possible risk-reducing mitigations. No attempt was made to translate into economic terms either the costs or the benefits associated with hazard-induced life loss, injury and illness, homelessness, and unemployment.

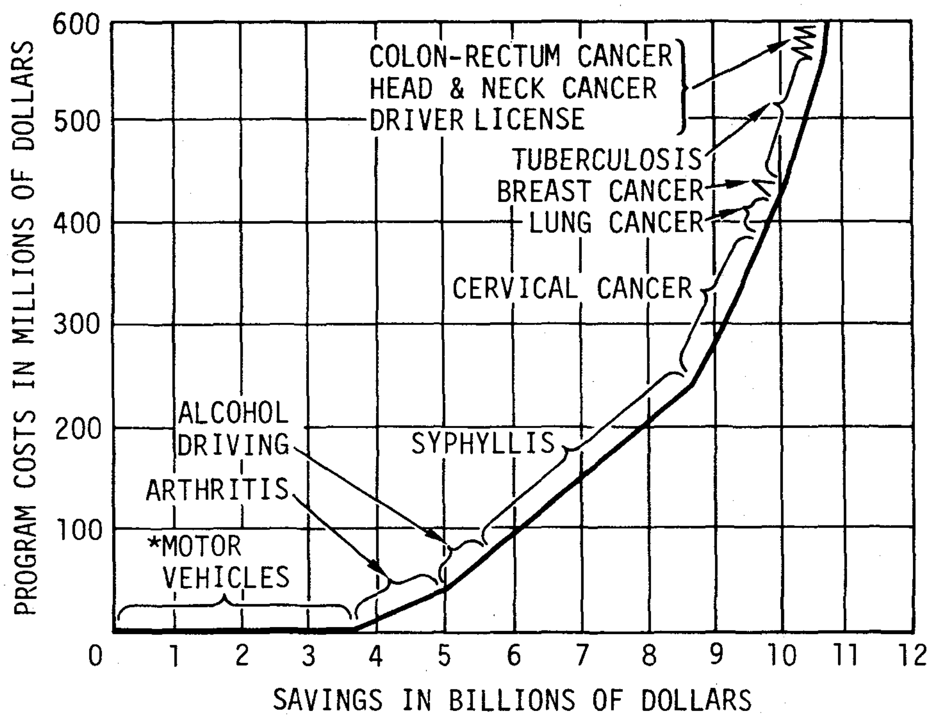
Similarly, no attempt was made to translate into economic terms the possible benefit associated with the "open space", "esthetic", and recreational gains which might be achieved through avoidance of development in riverine and coastal flood plains and other similar hazard zones. Neither, of course, were the possible disbenefits of such policies calculated. However, several observations may be made in respect to these matters:

(1) Life Loss:

The procedures used in the study to estimate life loss were based on assumed, but empirically-supported, relationships between the magnitude of dollar loss associated with hazardous occurrence and the loss of life also associated with such occurrences. [See Chapter 3] These procedures resulted in annual expected life loss estimates which were substantially greater for 1970 and 2000 than the annual average life loss for natural hazards which actually was reported for any of the decades in the current century [Dacy and Kunreuther (1969), p. 6]. Moreover, both hazard-induced death rates and the absolute annual average number of deaths from natural hazards has been declining rather steadily throughout the century. Thus, even though the estimates of life loss were probabilistically-derived and therefore reflect the intermittent and large losses of life which may be expected from major catastrophes (earthquakes, storm surge, hurricanes, etc.), the annual expected estimates of life loss nonetheless seem to err on the side of overstating the consequences of natural hazard exposures. We believe any such overstatement to be compatible with the objectives of public interest-oriented public policy-making. For example, the Working Group on Earthquake Hazards Reduction (1978) has suggested that "the primary objective of an earthquake hazards reduction program is to save lives," and the United Nations Disaster Relief Office similarly has urged that the highest priority target of national hazards management policies be the protection of human life (1976). Any overstatement of life loss which is a product of our estimates therefore errs in the direction of these ends.

Nonetheless, the annual expected estimates of life loss reported in this study are not impressive as compared with deaths from other causes in our society [See Chapter 4]. Moreover, it seems clear that the most effective means for avoiding hazard-induced life loss are those involving: (1) avoidance of high hazard areas; (2) hazard warning and population evacuation systems; (3) rapid extension of high quality emergency medical and survival-promoting services to disaster victims. Although the provision of area-protection facilities (dams, levees, seawalls, etc.) to hazard-prone communities may reduce the death rates that otherwise would be experienced in such areas, the very existence of these facilities may lure additional numbers of people into the hazard zone, unnecessarily increasing the sense of security of existing residents, and therefore increase the absolute number of deaths that otherwise would occur in these areas. Also, it is clear that dams sometimes fail, seawalls are over-topped, and the engineered limits of area-protection facilities sometimes are exceeded. On a comparative basis, therefore, logic requires that such mitigations be judged as less effective than avoidance policies. In the case of such hazards as earthquake of course, avoidance policies offer limited opportunities for life loss reduction and emphasis clearly must be placed on building strengthening and other structure-related strategies if large life losses from major seismic occurrences are to be avoided.

How to value reductions in life loss achievable through any type of mitigation is a perennial problem for analysts. We have approached this task, not as one of measuring the value of life, per se, but rather as an "opportunity cost" problem. Thus, it seems most appropriate to ask: What reductions in life loss from other causes must be foregone as a result of investments in natural hazard risk reduction programs? The question, of course, assumes at least three facts: (1) that insufficient resources are available to the nation to reduce all premature deaths to an effective level of zero; (2) that resources available for reducing life loss from natural hazards are, in theory, available for reducing life loss resulting from other causes; (3) the normative requirement governing the total national mix of life loss reduction programs is that of achieving the maximum attainable reduction in life loss per one million dollars invested in such programs. In these terms, it is interesting to note the following: If one were to make the obviously implausable assumption that the $7612-million-to-$17864.5-million annual escalation in net annual hazard costs resulting from use of the "most effective" mitigations shown in Table 5-31 would thereby purchase the complete elimination of all natural hazard deaths projected for 2000 (1790)*, then the net cost per life saved under this strategy would range from $4.09 million to $9.6 million. In contrast, Grosse [1972], has shown that the cost per death averted in four different cancer control programs in the period 1966-1972 ranged from a low of $2217 for uterine cervical cancers to a high of $46,181 for colon-rectum cancers. The cost reduction ratios found by Grosse are depicted in Figure 5-5.



SOURCE: Grosse [1972]

*Includes programs on use of seat belts, defensive driving, and reduction in pedestrian injuries

Figure 5-5. Dollar Saving in Cancer Programs Compared to Other Treatment Programs

Examination of this evidence suggests that the cost per life saved in natural hazard risk reduction programs can well be escalated to levels substantially in excess of those associated with other death and injury reducing programs which currently may be under-funded. Although this

*See Table 4-2. Riverine flood deaths have been measured in proportion to the higher baseline loss shown in Table 5-29.

inference is not intended to suggest that life loss reduction should not be an objective of natural hazard management programs (indeed, we believe the reverse to be true) neither does it seem appropriate to overstate the benefits associated with such programs and to understate the costs associated therewith.

(2) Other Social Costs:

Similar comments can be made in respect to the reductions in homelessness, income, and other psycho-social disbenefits associated with natural hazard exposures. If the minimum "pain" level of social disbenefits is to be the objective of natural hazard management programs, then it seems clear that hazard zone avoidance policies clearly have the edge over all other strategies. As in the case of life loss, moreover, it seems clear that the magnitude of these undesirable consequences of natural hazard exposures may easily be overstated. Thus, annual dwelling unit loss associated with highway construction and other public facility construction programs probably is substantially greater than the draw-downs on housing stock which may be charged to natural hazards exposures. Unemployment induced by changing Federal Reserve Board policies unquestionably is substantially in excess of that induced by natural hazards, and federal regulatory policies undoubtedly exert substantially more impacts on supplier costs than do natural hazard occurrences.

Conclusions

1. Annual expected losses from natural hazard exposures in 2000 may be reduced by more than 40% through application of currently-available risk-reducing technologies and policy mitigations.

Between 1980 and 2000 the application of selected combinations of building-strengthening, area structural protection, hazard zone planning, hazard zone avoidance, and building site preparation technologies can reduce annual expected building damage losses, alone, from $10,901.4 million to approximately $6,364.2 million [See Table 5-1]. Total annual expected losses may be reduced from $19,844.1 million to $12,012.6 million [see Table 5-31]. This level of mitigation would hold annual expected building damage losses to a value exceeding that of 1970 by only 10.6 percent, in spite of the substantial projected 1980-2000 increases in the size of the population exposed to significant natural hazards.

If mitigation costs are ignored, the largest achievable building damage loss reductions in 2000 are, in order of their magnitude (millions of $), as follows: (1) riverine flooding ($640.6 to $1,680.6); (2) storm surge ($841.2); (3) landslide ($521.8); (4) tornado ($494.0); (5) hurricane wind ($462.0); (6) earthquake ($294.5); (7) expansive soils ($237.0); (8) severe wind ($5.7); (9) tsunami ($0.4).

2. Overzealous application of strengthened building codes and standards can substantially increase net annual natural hazard costs in the year 2000.

The data generated by this study suggests that imprudent and overzealous application of risk-reducing mitigations can increase net annual expected natural hazard costs in 2000 by 38.4% to 90.0% above baseline, or "unmitigated" levels [See Table 5-31]. Net annual expected hazard costs are defined as annualized losses produced by hazard exposures plus the annual amortized costs associated with efforts to reduce those losses.

In terms of building strengthening strategies, in only a comparatively small number of U.S. counties are the annual expected loss reductions associated with the strategy equal to the annual amortized cost of the building-strengthening mitigation at 6.1% interest [See Table 5-21]. Only two non-California U.S. counties meet this test in respect to earthquake-related strategies; and only 229 for all wind hazards. In those counties in which loss-reduction-to-cost ratios were 1 to 1 or greater for the "most effective" building mitigation, estimated annual building damage losses in 1970 totalled only 11.08% of all national losses in the same year for all wind hazards, 4.82% for all non-California earthquake hazards, and only 12.5% for all storm surge losses [See Table 5-22].

In respect to riverine flooding, risk-reducing mitigation strategies which involve both the provision of area protection against fifty-year flood heights and requirements for four-foot floodproofing of all structures in fifty-year flood plains do not appear to be cost-feasible. Similarly, the elevation or floodproofing of all new structures in counties influenced by storm surge flooding does not appear to be economically feasible, but such strategies are feasible in sections of the coast lying below 20.1 feet, adjusted mean sea level.

Although building-strengthening strategies clearly are important loss-reducing tools, the study suggests that these strategies should not comprise either the whole or even a significant fraction of the nation's natural hazards management policy. Indeed, study findings contain within them the "hint" that current model building code requirements may well exceed economically justifiable levels if applied in numerous counties of the U.S. Examination of this possibility was beyond the scope of this project but seems clearly to be a subject worthy of future investigation.

3. Riverine and coastal area flood control facilities constructed in compliance with post-1936 economic criteria appear to be cost-effective methods for controlling losses at specified levels of hazard zone occupancy, but contribute to temporal increases in annual expected losses within the hazard zones.

For the overwhelming fraction of the current century, the construction of area protection facilities (dams, levees, seawalls, etc.) has, together with warning and population evacuation systems, comprised the primary U.S. public policy approach to the mitigation of risks associated with riverine and coastal flooding.

Based on the crude cost-feasibility tests applied to this policy in this study, it appears that--at the national level--the following conclusion is warranted: under a condition where community values decree that flood-prone lands are to be developed to the level currently exhibited by the sum of U.S. flood-prone urban communities, then the provision of these facilities seems to be cost-feasible, at 6.0% interest; viz. The annual loss reductions under conditions of development appear to be less than the annual amortized cost of the facilities. Optimistically, net annual savings from sea-wall protection of surge-prone coastal areas may be as high as $480 million per year in 2000. In 1970, annual net savings from construction of all prior riverine flood control works may have been as high as $595 million; and 1970-2000 investments in flood control works for 4,418 flood-prone communities could produce annual net savings in 2000 of approximately $570 million (at 9.0%) to $1,400 million (at 6.0%).

These estimates should be viewed as optimistic. They do not consider such potential disadvantages as ecological damage and the increase that might result in the absolute number of persons exposed to the hazards of dam failure and flood heights above the fifty-year level. Neither do they consider the possible downstream increases in water volumes resulting from higher runoff and lower water retention in flood-protected areas. Also, although tests of feasibility were based on both 6.0% and 9.0% interest levels, future annual net savings were not discounted to their current value. Also, the application of this strategy does not appear to be generally cost-feasible when combined with a flood plain avoidance strategy for new construction and--if applied above--would result in temporal increases in absolute annual losses from flooding.

4. The large "opportunity costs" associated with application of "most effective" mitigations [See Figure 5-1] suggest that the use of such mitigations is not an economically justifiable approach for curbing the life-loss associated with natural hazard exposures.

Even though the life-loss estimates generated in this study are on the side of overstating this consequence, annual expected life-loss resulting from natural hazard exposures is not high as compared with other causes of controllable premature death in U.S. society. Moreover, the use of "most effective" natural hazard mitigations--even under implausibly optimistic assumptions concerning their death-reduction effectiveness--results in extraordinarily high costs per death averted.

If a paramount objective of the total mix of national-level policies concerning environmental quality, work-place safety, natural hazards, and public and environmental health is to achieve maximal reduction in deaths from these causes at any constrained annual level of public and private investment, then other causes of premature death would warrant a higher policy priority. This conclusion seems justified even if the deaths-avoided findings are doubled and costs of death aversion are halved for the "most effective" natural hazard mitigations.

Also, logic suggests that hazard zone avoidance, hazard warning, and population evacuation systems and policies would prevent more hazard-related deaths than the across-the-board application of the "most effective" mitigations identified in this study.

In any event, the interests of rational, comprehensive, and compassionate public policy-making suggest that further intensive and quantitatively oriented study be directed at the costs and payoffs of alternative death- and injury-avoiding, environmental hazard programs, when such hazards are defined as including both those of "natural" and "man-induced" origin.

Chapter Six

CATASTROPHIC NATURAL HAZARD OCCURRENCES

Introduction and Summary

The cumulative natural hazard losses which may be charged to a particular place over any extended time frame are the product of two major types of events: (1) those which recur at a comparatively high level of frequency; (2) those which occur only rarely. In theory, over long time lines (100-200 years), the cumulative absolute and per capita losses charged to two different places may be exactly the same. Under event type one, however, the losses may be concentrated in only a few years as a result of a small number of hazardous occurrences, while in the other, a more statistically normal year-by-year distribution of losses may be exhibited.

In places where large fractions of cumulated losses may be incurred over a long time frame as a result of infrequently-occurring catastrophic events, policymakers or exposed citizens may wish to consider not the probabilistically-derived annual expected loss level associated with a particular type of hazard exposure, but rather the episodic level of loss associated with the low probability event. In effect, the exposed population may wish to place a probability of 1.0 on the occurrence of a catastrophe and then seek an optimal approval to the minimization of loss during the anticipated episode.

Accordingly, this study focused also on development of such loss estimates for two low-probability events: a recurrence of the "great" San Francisco earthquake, and a recurrence of Hurricane Camille.

Approach to Scenario Development

If a scenario is to serve any useful purpose, it must be believable. Thus, in examining the consequences in the year 2000 of a recurrence of two of the most severe catastrophes in the nation's history, no alterations in the significant facts associated with the original events were made. The scenario deals only with the anticipated demographic and economic attributes of the two target areas in the year 2000.

Thus, what the consequences of Camille would be if her landfall were shifted slightly westward so that she would strike with full force on New Orleans instead of Gulfport, Mississippi was not addressed. Nor what would happen if the San Francisco earthquake were to reoccur at high noon instead of 5:13 A.M. Yet, either of these alterations in the essential facts of the original occurrence is both believable and possible and either change would substantially alter the estimates of life and property loss presented in the following scenarios.

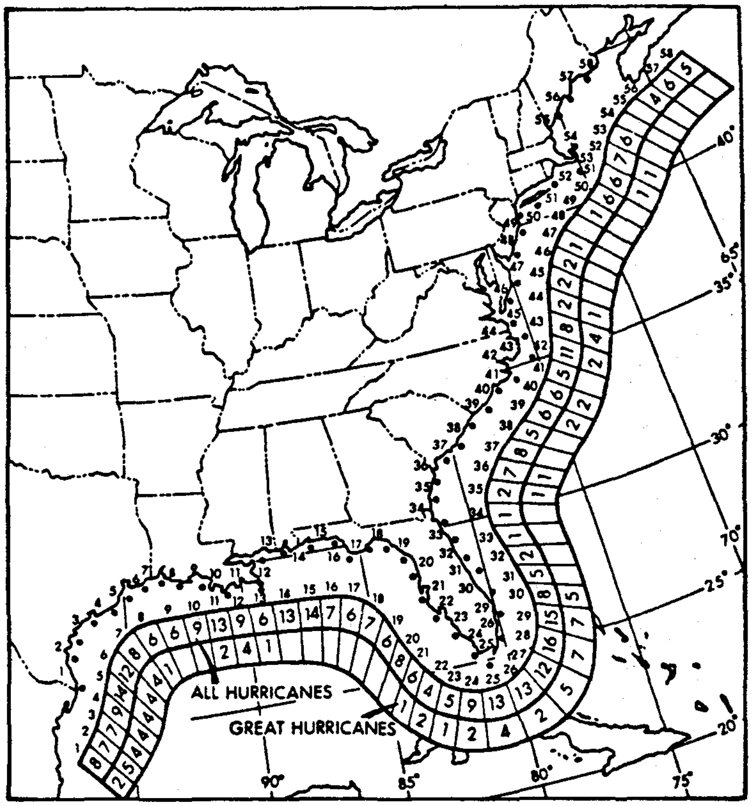
Camille II

Approximately 3000 miles of the U.S. coastline are vulnerable to either "land falling" or "land existing" storms of hurricane forces [Hart, 1976]. Reaching from Port Isabel on the Texas coast to Eastport in Maine, this hurricane-vulnerable stretch of coastline contained a 1970 population of 62.74 million persons and $682 billion in building wealth which were at risk of exposure to winds of hurricane velocity. Also, a population of 38.39 million persons and a building wealth of $438 billion were at risk of exposure to hurricane-related storm surges [Derived from: Hart (1976), Lee (1976)].

However, between 1931 and 1972, only 77 hurricanes touched any part of the coastline, and only a few of these could be classed as "great" hurricanes, with wind velocities in excess of 125 mph. Given the twin facts that fewer than two hurricanes per year of any type have visited this coastline over the 41-year period and the fact that the typical hurricane spins winds of hurricane force over an area of only 100 square miles in diameter and gale-force winds over an area only 400 miles in diameter [Hart, (1976)], it is clear that the annual probability that any given segment of the coast will experience a hurricane is low indeed.

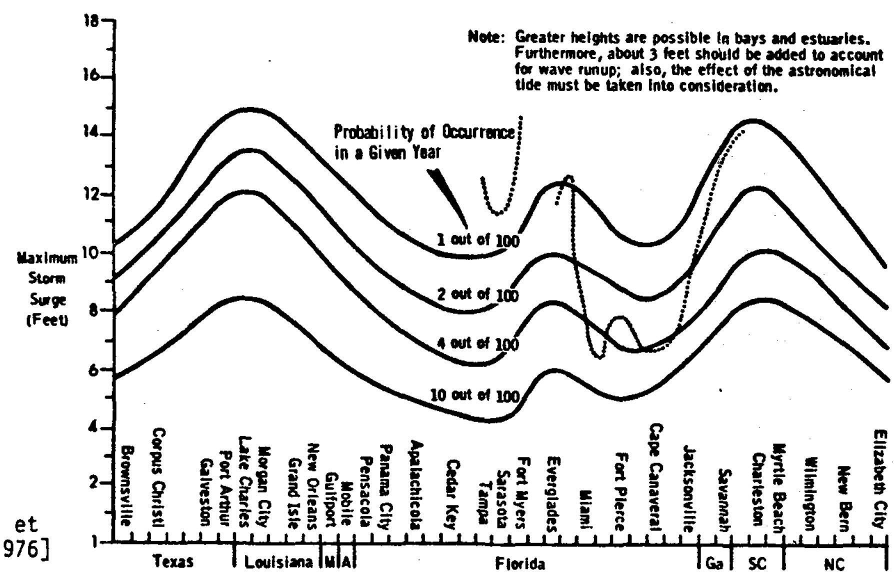
As shown in Figure 6-1, the probability in any given year that any given 50-mile segment of the coastline will experience a hurricane-force storm varies from 0.0% to 1.0% for seven segments to 14.0%-or-more for four segments. The annual probability of a "great" hurricane (winds in excess of 125 mph) varies from 0.0-1.0% for 37 segments to 4.0% or more for only thirteen segments.

As depicted in Figure 6-2, similar low probabilities are exhibited for hurricane-induced storm surges. Of course, no matter what the probability of a hurricane strike may be for any specific place, when such an event does occur, the results can be devastating. That was the case with Hurricane Camille in August 1969.



Source: White, et al. [1976]

Figure 6-1. HURRICANE PROBABILITY MAP - Probability (percentage) that a hurricane (winds exceeding 73 mph) or great hurricane (winds in excess of 125 mph) will occur in any one year in a 50-mile segment of the U.S. coastline [after Simpson and Lawrence, 1971]



Source: White, et al. [1976]

Figure 6-2. COMPOSITE ESTIMATES OF EXPECTED SURGE HEIGHT - Solid lines based on U.S. Army Corps of Engineers and University of Florida probability estimates of annual occurrence of a storm surge on an open beach area [Friedman, 1971]; dotted lines based on National Oceanic and Atmospheric Administration (1971a, 1972a, 1973, 1973a), probability of occurrence is 1 out of 100.

One of the most intense hurricanes ever known to enter the United States, Camille resulted in the deaths of 262 persons and the destruction of thousands of buildings; estimated losses exceeded one billion dollars.

From the point of landfall, Hurricane Camille moved north across Mississippi and continued her destructive path inland. In addition to coastal zone damage resulting from storm surge and high winds, Camille contributed to heavy rains in Tennessee, Kentucky, West Virginia, and Virginia, which, in turn, caused flash floods and mudslides. The James River rose to a record high, wreaking havoc on river towns from Lynchburg to Richmond, Virginia.

In this study, an exact repeat of Camille has been examined, but under the demographic and economic conditions predicted for the target area in the year 2000. Also, for purposes of this scenario, only the results of Camille-related storm surge and hurricane winds will be examined; the aforementioned riverine flooding and mudslides are not included. Figures 6-3 and 6-4 indicate the nature and severity of the hurricane. These exhibits portray the landfall area and intensities of storm surge on a theoretical Hurricane Camille, circa 2000. They were based upon data in a U.S. Army Corps of Engineers' report on Hurricane Camille [1969].

Figure 6-3 shows the path of Hurricane Camille. The distribution of wind velocities at point of landfall is shown in Figure 6-4, e.g., winds will reach well above 175 miles over an approximate 20-mile coastal section from Biloxi to Mississippi City, Mississippi. At their most severe, winds will exceed 200 miles per hour. Thereafter, they will diminish to about 75 miles per hour, 50 miles to the west and 60 miles to the east of the storm center. Distribution of wind intensities by county within the major impact area are shown in Table 6-1. Note that two counties receive major velocities above 200 miles per hour: Hancock and Harrison Counties, Mississippi. Both are at the point of landfall. Figure 6-5 shows the high-water profile associated with the coastal storm surge in the impact area.

Defined 28-County Impact Area

Should an exact repeat of Hurricane Camille occur in 2000, a 28-county impact area will be affected, as shown in Figure 6-6. The area covers approximately

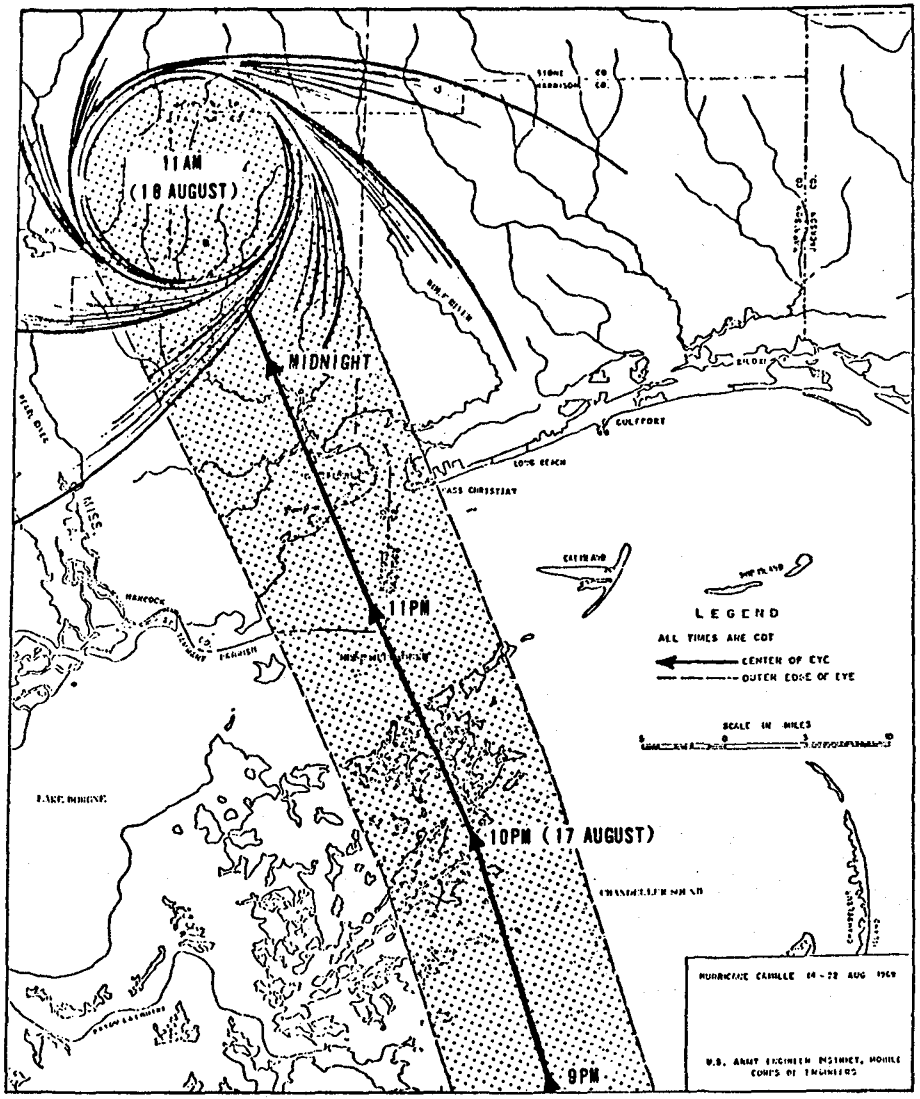


Figure 6-3. Path of Hurricane Camille at Landfall

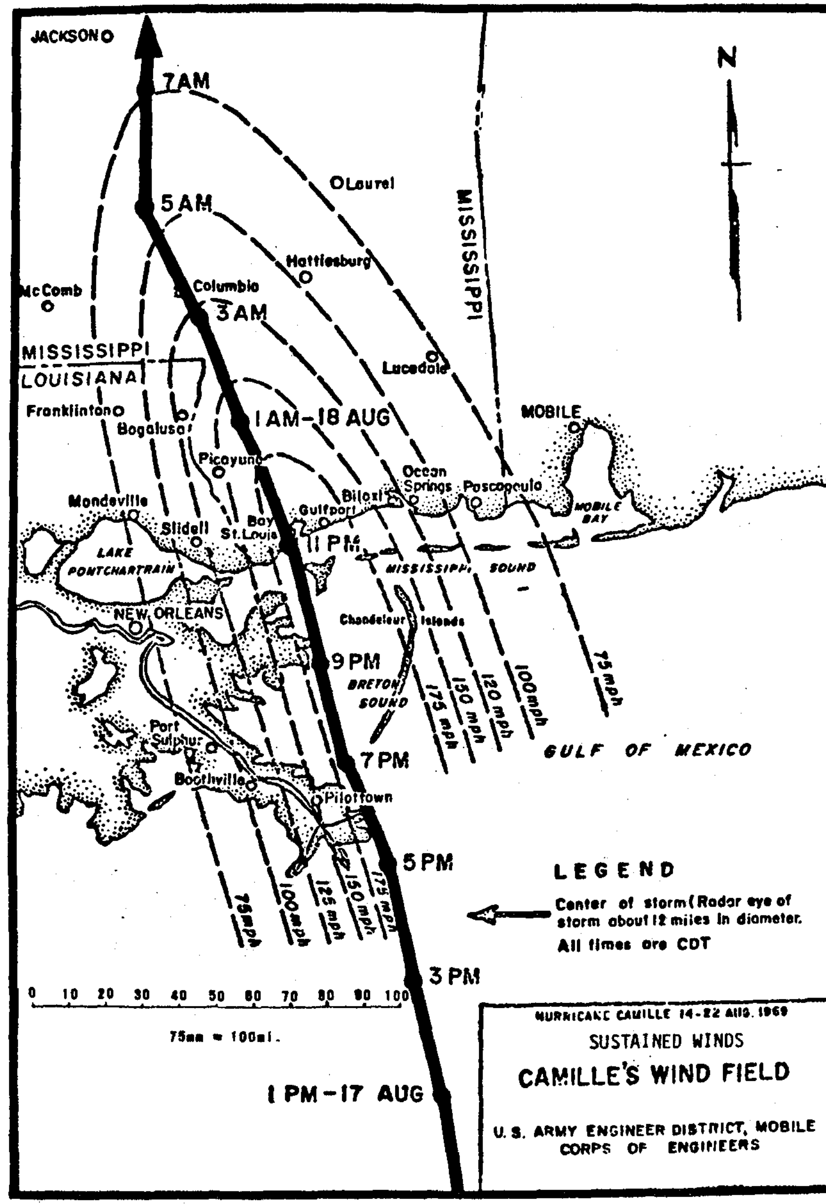


Figure 6-4. Camille's Wind Field

COUNTY	MEDIAN WIND SPEED (MPH)	WIND SPEED RANGE (MPH)					
		<75	75-100	101-125	125-150	151-200	>200
PLAQUEMINES, LA	90	35	25	25	10	5	
ST. BERNARD, LA	112	5	30	30	30	5	
ORLEANS, LA	83	40	30	30			
ST. TAMMANY, LA	108	10	30	30	30		
WASHINGTON, LA	91	25	40	20	15		
GREENE, MS	<75	90	10				
PEARL RIVER, MS	129			40	60		
HANCOCK, MS	200					50	50
HARRISON, MS	150			20	30	30	20
STONE, MS	111	15	15	45	25		
JACKSON, MS	87	20	60	20			
GEORGE, MS	79	40	60				
WALTHALL, MS	92		75	20	5		
MARION, MS	117			70	30		
LAWRENCE, MS	87	5	90	5			
SIMPSON, MS	84	20	80				
JEFFERSON DAVIS, MS	104		40	60			
COVINGTON, MS	89		90	10			
JONES, MS	<75	55	45				
PERRY, MS	85	25	60	15			
MOBILE, AL	<75	99	1				
LAMAR, MS	121			60	40		
FORREST, MS	100		50	50			

Table 6-1. Percent Distribution of Wind Speeds by County in Hurricane Target Area

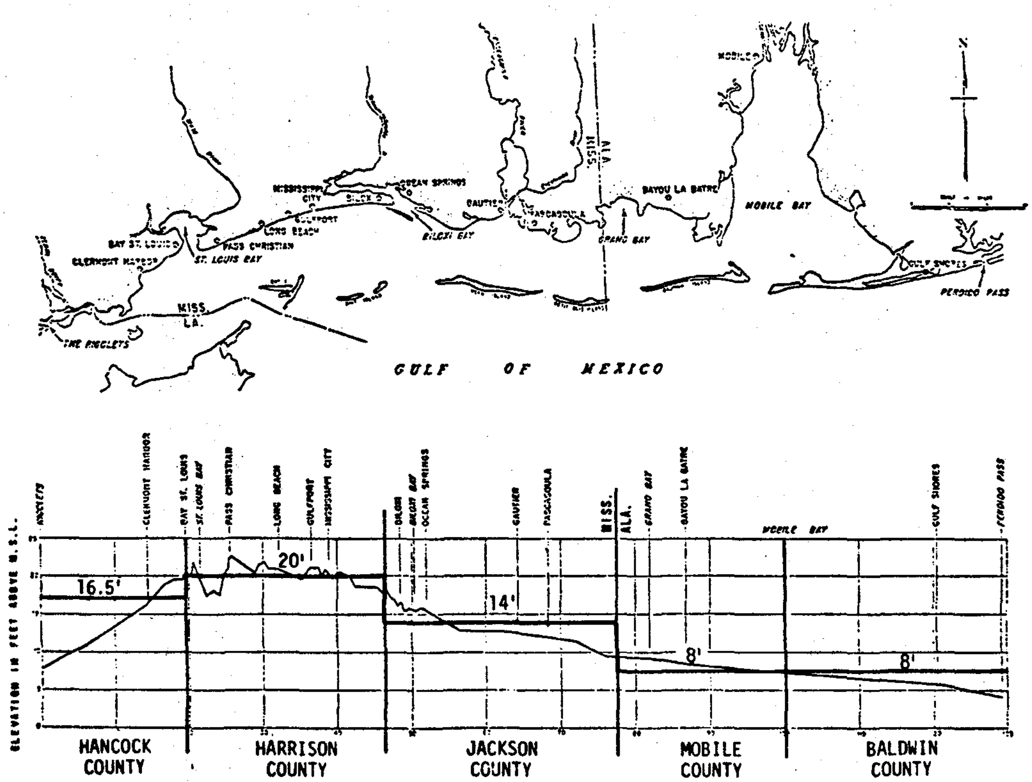


Figure 6-5. Hurricane Camille, High-water Profile

400 miles of coastline in Louisiana, Mississippi, Alabama and Florida. Twenty-three of the 28 counties will be subject to wind damage, ten of the counties will be subject to flood damage, and five of the counties will be subject to both. In reality, only the coastal portion of the ten "flood-damage counties" is subject to flooding. However, for purposes of this paradigm, the total county is considered as an economic impact area for coastal flooding.

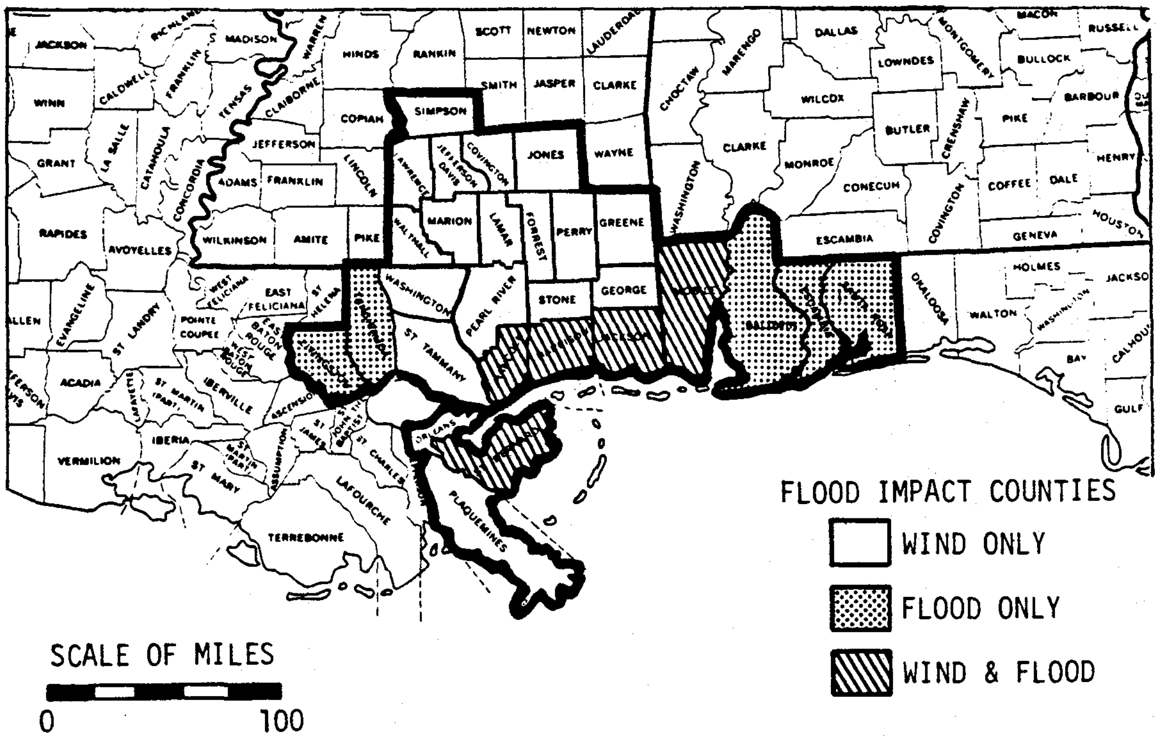


Figure 6-6. Twenty-eight County Impact Area

For each of the 28 counties in the total impact area, 1970 values of economic measures were projected to the year 2000 utilizing the economic model discussed earlier. Base measures projected include population, per capita income, total economic value at risk, and building valuation at risk. Table 6-2 indicates population and per capita income for the year 2000 for each county. The 28-county area population in the year 2000 is projected to be approximately 2,335,200, an increase of 15% over 1970 population of 2,026,600. Similarly, average per capita income in the year 2000 of $6332 (expressed in 1970 constant dollars) versus $2547 for 1970, reflects an increase of real income in the 30-year period. (Per capita income was computed from County & City Data Book - 1972, U.S. Dept. of Commerce; and figures adjusted according to Obers Projections, Vol. 2, U.S. Water Resources Council, for 1970 and 2000 expressed in 1970 dollars.)

Figure 6-7 shows total economic value of buildings-at-risk in the 28-county area as approximately $44 billion in the year 2000 (in 1970 constant dollars). Total value at risk for the full 28-county impact area is approximately $18,900 per capita (expressed in 1970 constant dollars for the year 2000). This figure varies only slightly from county to county within the full 28-county impact area (see Figure 6-8).

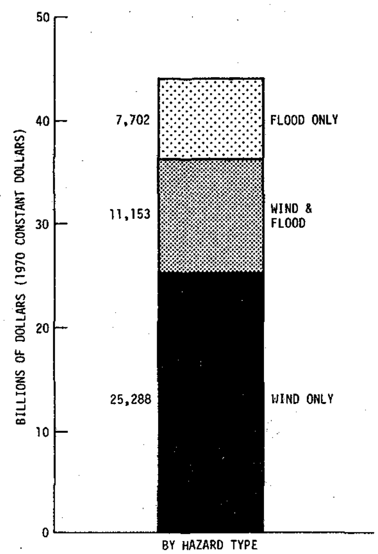


Figure 6-7. Year 2000 Economic Value of Buildings at Risk in Twenty-eight County Impact Area

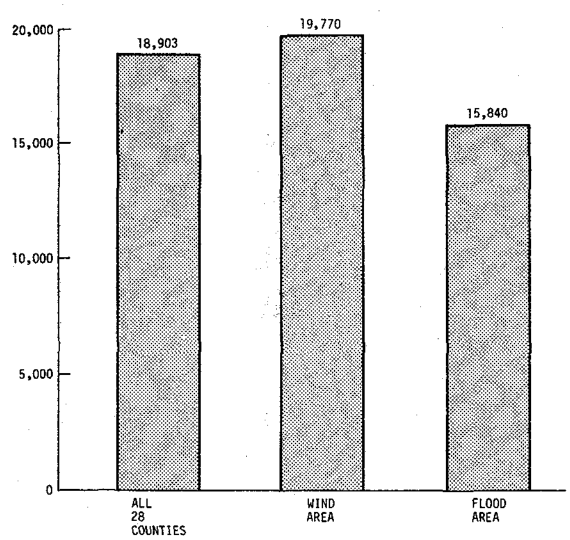


Figure 6-8. Per Capita Economic Value at Risk Twenty-eight Counties, Year 2000

COUNTIES	POPULATION (1000's)		PER CAPITA INCOME (1970 DOLLARS)	
WIND AND FLOOD	1970	2000	1970	2000
Mobile, AL	317.0	368.0	2548	6453
St. Bernard, LA	51.2	57.4	2790	6856
Hancock, MS	17.4	17.2	2227	5472
Harrison, MS	135.0	162.0	2447	6195
Jackson, MS	88.0	93.7	2673	6770
TOTAL	608.6	698.3		
WIND ONLY				
Orleans, LA	593.0	665.0	2874	7062
Plaquemines, LA	25.2	28.6	2484	6104
St. Tammany, LA	63.6	71.3	2736	6723
Washington, LA	42.0	49.4	2128	5229
Covington, MS	14.0	15.3	1830	4908
Forrest, MS	57.8	63.1	2476	6644
George, MS	12.5	15.0	2051	5193
Greene, MS	8.6	10.3	1473	3730
Jefferson Davis, MS	12.9	15.2	1646	4044
Jones, MS	56.4	61.6	2321	6228
Lamar, MS	15.2	16.6	2080	5580
Lawrence, MS	11.1	13.1	1821	4475
Marion, MS	22.9	26.9	1713	4208
Pearl River, MS	28.7	33.8	2135	5245
Perry, MS	9.1	9.9	1689	4532
Simpson, MS	19.9	25.6	1835	4639
Stone, MS	8.1	9.7	2001	5067
Walthall, MS	12.5	14.7	1785	4386
TOTAL	1013.5	1145.1		
FLOOD ONLY				
Baldwin, AL	59.4	68.8	2387	6045
Escambia, FL	205.0	269.0	2617	6258
Santa Rosa, FL	37.7	49.4	2514	6012
Livingston, LA	36.5	37.3	2247	5522
Tangipahoa, LA	65.9	67.3	1814	4456
TOTAL	404.5	491.8	2547	6332
GRAND TOTAL	2026.6	2335.2		

Source: 1972 Obers Projections, Vol. 2 U.S. Water Resources Council

Table 6-2. Twenty-eight County Economic Measures

Economic Loss Without Mitigation

Summary Losses (1969 Versus 2000)

Projected losses, both economic and non-economic, are summarized in Figure 6-9; these figures do not incorporate mitigation. Losses for the 1969 event are compared with projections of loss for the year 2000 -- an estimated $5.9 billion for the 28-county area (in 1970 constant dollars). Non-economic loss projections include 642 deaths, 68,000 person-years of unemployment, and 64,000 person-years of homelessness. These loss levels--up to four times those of 1969--reflect projected population growth, greater coastline development, and detailed factors incorporated in the economic projection model on a sub-area basis.

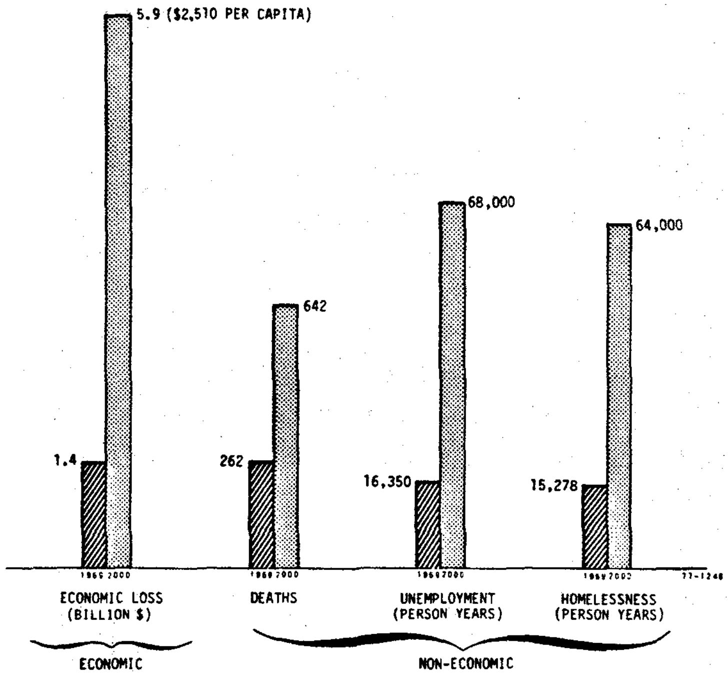


Figure 6-9. Loss Comparisons - 1969 Event vs. 2000 Scenario Without Mitigations

Per Capita Economic Loss

The $5.9 billion economic loss in the year 2000 would approximate $2510 per capita for 2,335,200 residents of the 28 counties [See Figure 6-10]. These per capita losses vary significantly within the total impact area; the greatest losses occurring in Hancock and Harrison Counties, the storm center. Total per capita losses range from a high of about $16,000 to a low of under $100 within individual counties.

As compared with average per capita losses of $2510, the data in Table 6-3 indicates that one-half of the counties will experience losses of less than $1000 per capita. This differential indicates that several of the counties will suffer extremely high losses. The heaviest per capita losses by far would be in the three counties in the path of the hurricane: Hancock, Harrison, and Pearl River Counties.

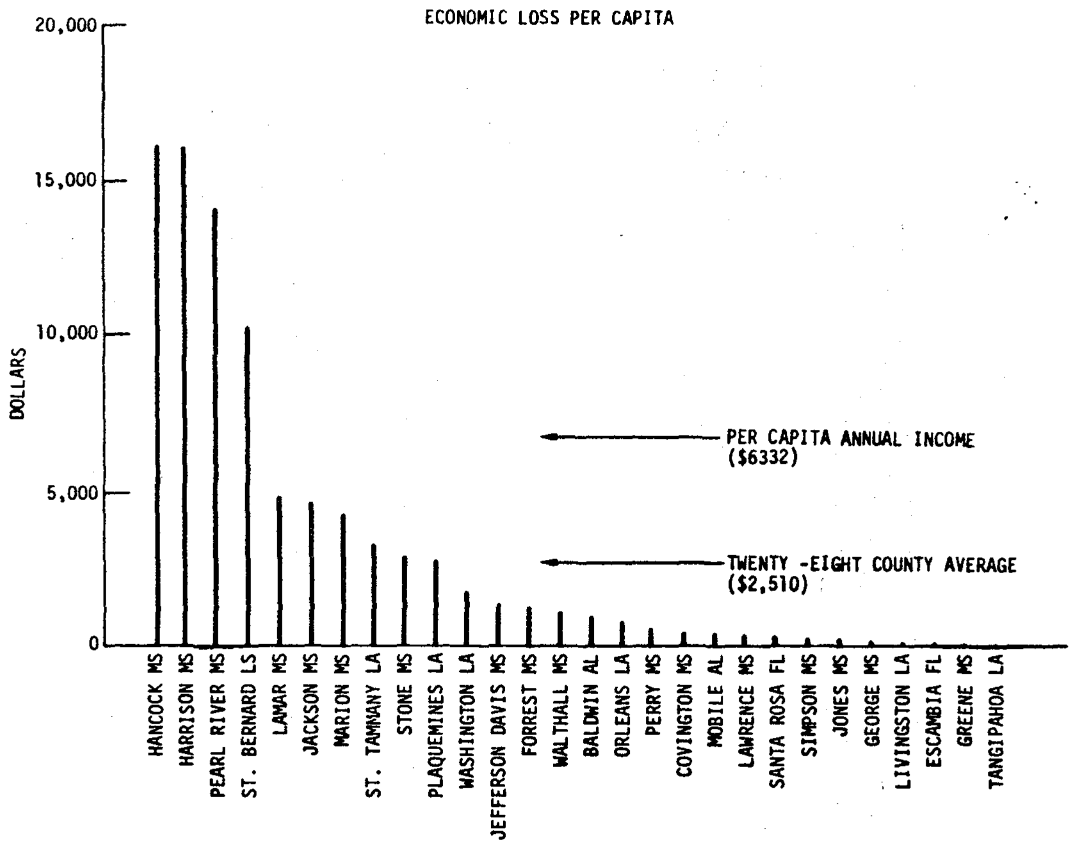


Figure 6-10. Per Capita Economic Loss Comparisons for Twenty-eight Counties in the Year 2000 Due to Hurricane Camille

DOLLAR LOSS			NUMBER COUNTIES	PERCENT TOTAL
UNDER		$ 100	4	14.3
$ 100	-	499	7	25.0
500	-	999	3	10.7
1,000	-	1,999	4	14.3
2,000	-	2,999	2	7.1
3,000	-	3,999	1	3.6
4,000	-	4,999	3	10.7
5,000	-	$9,999	-	-
$10,000	AND	OVER	4	14.3
TOTAL			28	100.0

MEDIAN $1,000
AVERAGE $2,510

Table 6-3. Year 2000. Per Capita Economic Loss Without Mitigation, Distribution by County ($1970)

Economic Losses Related to Per Capita Income

Projected economic loss of $5.9 billion for the 28-county impact area equals 39.6% of per capita income (projected to be $6332 in 1970 constant dollars). Figure 6-11 and Table 6-4 indicate these percentages vary widely by county, from a high of 294% in Hancock County to below 10% in eleven counties.

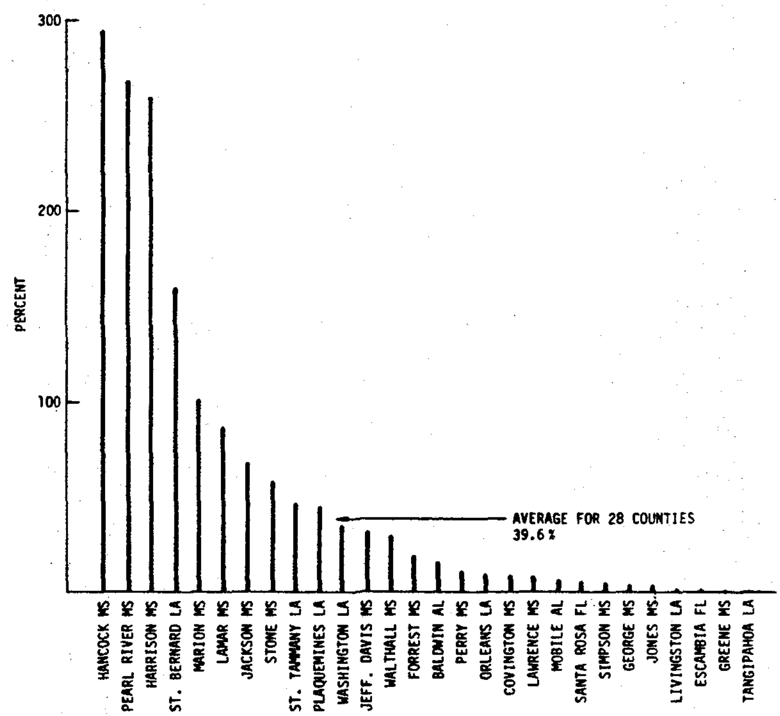


Figure 6-11. Per Capita Economic Loss Comparisons as Percent of Per Capita Annual Income (Without Mitigation - Year 2000)

PERCENT OF INCOME	NUMBER COUNTIES	PERCENT TOTAL
UNDER 1.0%	3	10.7
1.0 - 4.9	5	17.9
5.0 - 9.9	3	10.7
10.0 - 24.9	4	14.3
25.0 - 49.9	5	17.9
50.0 - 99.9	3	10.7
100.0 - 199.9	2	7.1
200.0 - 300.0	3	10.7
TOTAL	28	100.0

MEDIAN 17.0%
AVERAGE 39.6%

Table 6-4. Year 2000, Per Capita Economic Loss as Percent of Per Capita Income

Distribution of Economic Loss by Type of Property

Composition of economic loss for the 28-county area is indicated in Figure 6-12. Building losses will be approximately $2.7 billion, about 46% of total economic losses. The principal contributor to building loss would be hurricane winds--roughly two-thirds of the total--with the remainder caused by floodings. "Other" includes supplier loss, which covers the extra costs of acquiring goods and services which would ordinarily be from a closer source. Building contents includes all contents except food and other nondurable goods; the exception is inventories for food stores and eating establishments. Income loss is loss in take-home pay caused by a company's closing or one of its buyers being closed or out of business.

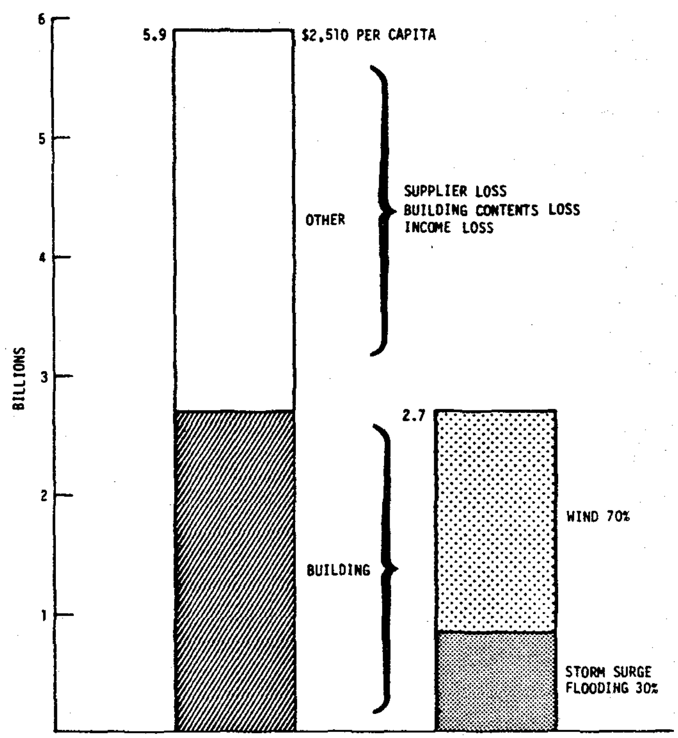


Figure 6-12. Year 2000 Economic Loss--Without Mitigation, Twenty-eight County Impact Area

Economic Loss Distribution by Family Income Group

Table 6-5 compares population distribution to distribution of economic loss by family income group. It is projected that economic loss would be roughly in proportion to population; no single income group would bear an inordinately-high share of the loss. In this analysis, however, no attempt has been made to determine the amount of loss which various income groups could "afford". While disruption of a high income family would be a considerable inconvenience, they might have sufficient reserves to cover short-term losses. A lower income group, however, might be ruined by a loss situation equal in amount.

INCOME CATEGORY	POPULATION DISTRIBUTION (PERCENT)	H & SS TOTAL ECONOMIC LOSS DISTRIBUTION (PERCENT)	DIFFERENCE (PERCENT)	STORM SURGE LOSS DISTRIBUTION (PERCENT)	HURRICANE LOSS DISTRIBUTION (PERCENT)
1. LESS THAN $3,000 ANNUAL FAMILY INCOME	16.6	15.9	<0.7>	12.6	17.4
2. $3,000 to $4,999	13.2	13.7	0.5	12.0	14.5
3. $5,000 to $6,999	14.0	16.4	2.4	15.9	16.6
4. $7,000 to $9,999	25.6	21.9	<3.7>	23.9	20.9
5. $10,000 to $14,999	19.0	20.9	1.9	23.7	19.7
6. $15,000 to $24,999	8.9	9.2	0.3	10.0	8.9
7. $25,000 and OVER	2.7	2.0	<0.7>	1.9	2.0
TOTAL	100.0	100.0	0	100.0	100.0

Table 6-5. Hurricane Camille Scenario for the Year 2000

Non-economic Losses

As shown earlier in Figure 6-10, three types of non-economic loss have been projected: mortality, unemployment, and homelessness. This list is not intended to be all-inclusive; educational disruption and social dislocation are examples of other possible losses which have not been considered here, but are nevertheless important factors.

Mortality

Six hundred and forty-two deaths are projected for the year 2000 from Hurricane Camille--approximately two and one-fourth times 1969 fatalities. As with economic losses, the high loss figure results from population growth and greater utilization of coastline areas. This means approximately one person out of each 3,600 in the 28-county impact area would die from the hurricane. While one in 3,600 may not seem significant, it compares unfavorably to other accidental mortality figures. For example, the 642 deaths from Hurricane Camille in the year 2000 is equal to 40% of the average aircraft deaths per year in the United States (over the last ten years). [Accident Facts, 1975]

Unemployment

Unemployment for the 28-county area is projected at 68,000 person-years. In the detailed economic model, it is assumed unemployment would not extend beyond one year. However, this understates total unemployment, as some facilities may be shut down permanently as a result of Hurricane Camille. The amount of unemployment as a percentage of the total work force would depend upon the duration of unemployment; this obviously varies from job-to-job. Figure 6-13 shows that a full year of unemployment (obviously quite high), would affect approximately 7.3% of the 28-county labor force. This unemployment would be added to "normal" unemployment of approximately 6%. As a consequence, total unemployment for the region--assuming this one-year duration--would be above 13%. Assuming a three-month duration of unemployment, over 29% of total work force would be affected, forcing total unemployment (normal and Camille) above 35%.

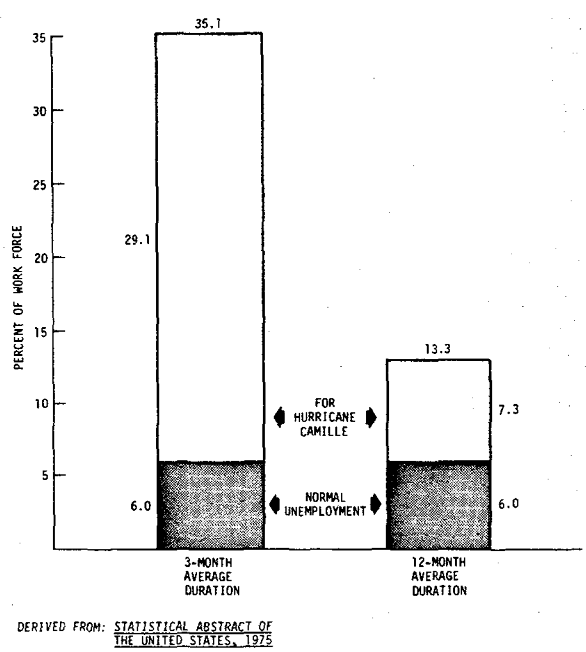


Figure 6-13. Unemployment Comparisons for the Year 2000

As with mortality, no measure of unemployment can fully represent social impact. However, these figures indicate potential unemployment from Hurricane Camille to be of significance.

Homelessness

It is estimated that 64,000 person-years of homelessness would result from Hurricane Camille. A person-year of homelessness is one person displaced from his or her home for 365 days. In reality, most victims would be away from their home a much shorter period. Immediately after the storm, an estimated 800,000 people would be homeless for at least one day, 500,000 for more than one week, and more than 100,000 for more than one month. Average homelessness duration for the population is estimated at two months.

These numbers are significant in that they indicate approximately one-third of the total population would be homeless for at least one night, and more than 10% for over a week. It is impossible to estimate the consequences of this displacement in terms of interruption of work, education, and other activities.

Possible Mitigation Measures and Their Costs of Implementation

The ability to exercise control over and reduce losses from such a natural event as Hurricane Camille exists. In this scenario, four mitigation measures have been considered:

1. Flood-proofing. After 1980, flood-proof all structures within a defined storm surge zone to the four-foot water level.
2. Increased Wind-design Code Provisions. Increase building codes for the region. All new structures built within the affected counties must meet a lateral wind force standard equivalent to three times that of the 1973 Uniform Building Code.
3. 100-year Storm Sea Wall. Protect all counties within a defined storm-surge zone through construction of a storm sea wall capable of withstanding 100-year storm conditions.
4. No Growth. Allow no further growth on the 50-year floodplain after 1980.

These four measures are by no means the only ones available. However, they reflect enough variety for analytical evaluation.

Dollar Costs of Mitigation

In this scenario, costs have been projected for only the first two mitigations (flood-proofing and wind-design), which are of a structural nature. As shown in Figure 6-14, total cost for implementation of these mitigations throughout the 28-county area (23 counties for wind and 10 counties for flood protection), is estimated at $6.0 billion. It is assumed this money would be expended over a 20-year period as new construction occurred. To calculate the overall cost of mitigation (structural only) in 1970 dollars, construction cost increases were projected between years 1980 and 2000; the increases were then compounded using a 6.1% interest rate. This accounts for the corresponding appreciation in value that would occur if the funds spent on extra building costs had been invested at an annual rate of 6.1% interest.

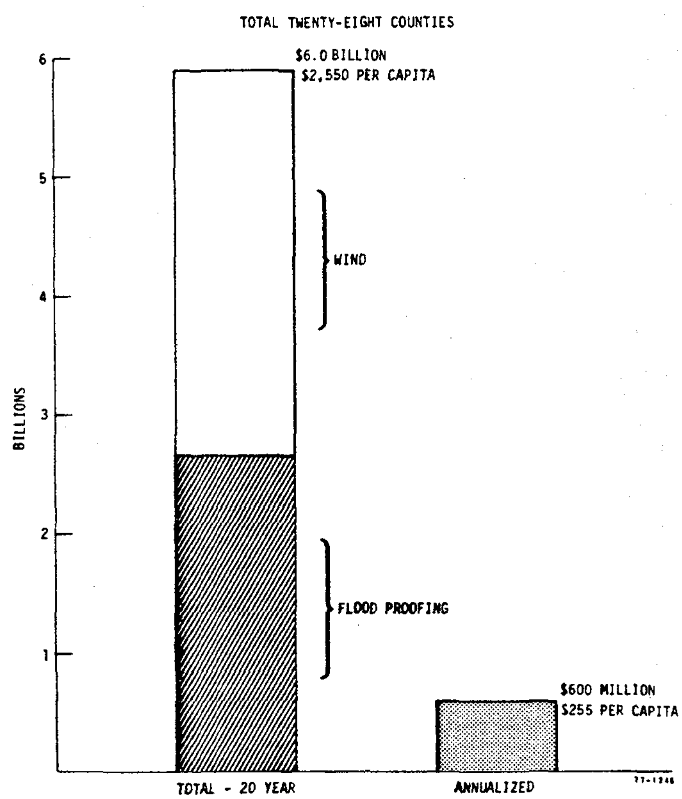


Figure 6-14. Costs of Mitigation (Structure Only)
Hurricane Camille, Year 2000

Per Capita Costs of Mitigation

Figure 6-15 shows annual mitigation costs equal to about $255 per capita, or about 4.0% of per capita income. Figure 6-16 fixes these annual costs at an average of about $115 per capita for flood-proofing (within the ten flood-vulnerable counties) and $140 per capita for wind protection (within the 23 wind-vulnerable counties). This might be compared to the cost of municipal service: about $170 per capita. (Municipal service covers the cost of police, fire, streets, sanitation, trash collection, library, parks and recreation and city administration). The total estimated cost of $6.0 million for mitigation equals approximately 13.4% of the total value at risk (building values). The annual mitigation costs of approximately $255 is equal to 4.0% of per capita income [See Figure 6-15]. When comparing mitigation costs of $255 per capita to the "normal" costs of providing municipal services (an average of approximately $170 per capita), the cost of mitigation is relatively substantial.

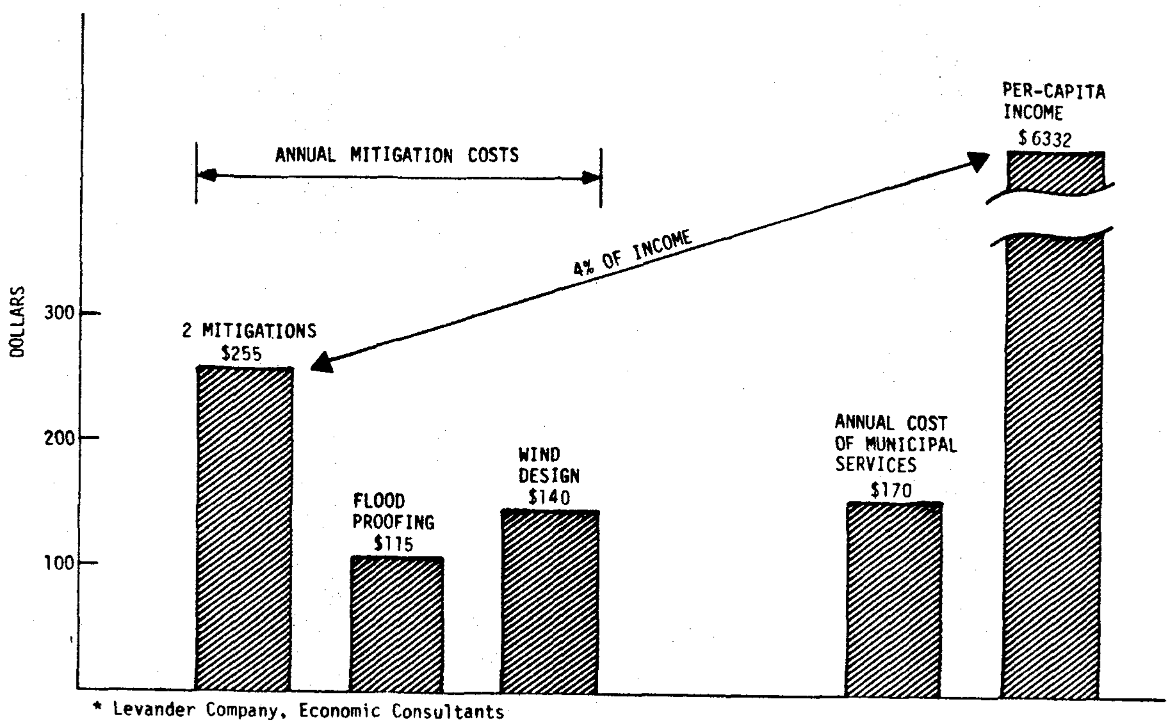


Figure 6-15. Annualized Costs of Mitigation (Structural Only) Per Capita Comparisons, Year 2000

In this analysis, it has been assumed that precautions against flood would be implemented throughout the flood-impact zone. Possibly, a smaller area would actually be protected. However, this would mean a smaller base over which to spread the costs (assuming some form of self-sufficient financing).

Wind protection would extend well beyond the defined wind-impact area, involving much heavier expenditures than those projected in this scenario. Presumably, such costs could be spread over a 1,000 mile area, including the entire Gulf and part of the Atlantic coastline. Nevertheless, per capita figures are reasonably representative.

Economic and Social Costs of No Growth

No cost estimate of the mitigation alternative of no growth has been made in this scenario. It might reasonably be expected that lack of growth in a given flood protection area would be offset by growth elsewhere in the region. Higher costs in small geographic areas could result in considerable economic dislocation, higher population in adjoining areas, and other problems.

In addition, property values within the zone could be adversely affected. And, within a micro-regional setting, building contractors and business people within flood zones could be negatively influenced. Correspondingly, employees of impacted firms could be affected. In this scenario analysis, no attempt has been made to quantify these social costs; however, they must be acknowledged. A more thorough discussion is presented later of specific stakeholder impacts resulting from hazards and mitigations.

Loss Reductions From Structural Mitigations

Table 6-6 indicates implementation of flood-proofing and a wind-design code would result in significant loss reductions for the 28-county area. With these mitigations, total losses for the year 2000 (in 1970 constant dollars) would be approximately $2.5 billion, whereas losses without mitigation would be $5.9 billion. This reflects a gross savings of $3.4 billion, or 58%. Flood-proofing will reduce loss approximately 47.5%; protection against wind will reduce loss by 31.3%.

	LOSSES WITHOUT MITIGATION *	LOSSES WITH MITIGATION *	LOSS REDUCTION *	PERCENT
TOTAL	5,861	2,481	3,380	58
BUILDING	2,390	1,515	875	37
OTHER	3,471	966	2,505	72
TOTAL	5,861	2,481	3,380	58
BUILDING ONLY				
FLOOD-PROOFING	790	415	375	47.5
BUILDING CODE	1,600	1,100	500	31.3
TOTAL	2,390	1,515	875	36.6

* MILLION

Table 6-6. Hurricane Camille, Savings After Implementation of Two Structural Mitigations - Year 2000

Figure 6-16 illustrates a sharp difference between the costs of mitigation and the total loss that would occur in the absence of the mitigations. Estimated loss reductions (with structural mitigation) in each county are detailed in Figure 6-18. Cost and loss reduction ratios were established for each county and for each structural mitigation. Cost and loss reduction estimates presented in Figure 6-17 indicate summary cost-loss reduction ratios would be:

Total(Two Mitigations)	1.74
Wind-design	1.31
Flood-proofing	3.23

Cost/loss reduction ratios above 1.0 indicate higher costs than loss reduction, and thus, an unfavorable condition for the 28-county area. Within the impact area of 28 counties, there is significant variation. However, only a few counties (those hardest hit) show favorable cost-feasible ratios (under 1.0)--for wind design only.

These ratios imply that it is not practical--on a purely economic basis--to implement the two structural mitigations. However, other justifications may be offered, including the alternative costs for insurance, and the value associated with prevention of an impact on a related set of communities.

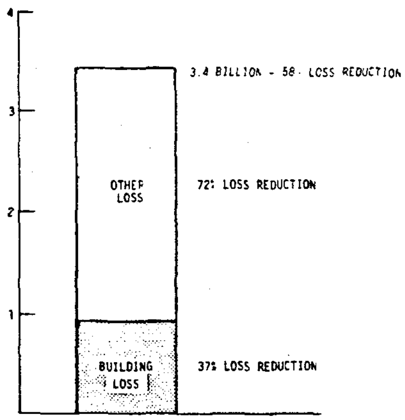


Figure 6-16. Mitigation Loss Reduction

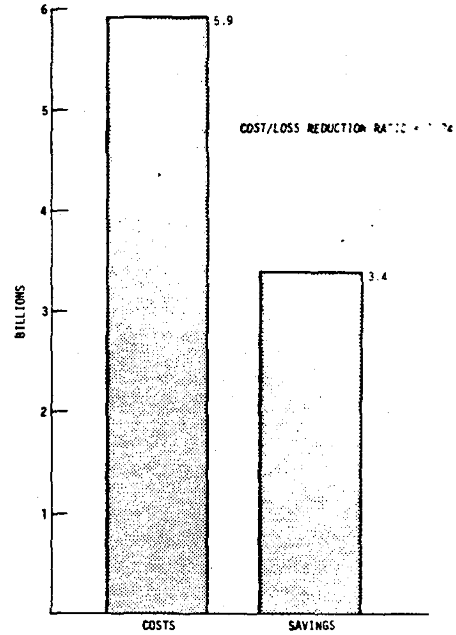


Figure 6-17. Mitigation Costs & Loss Reduction

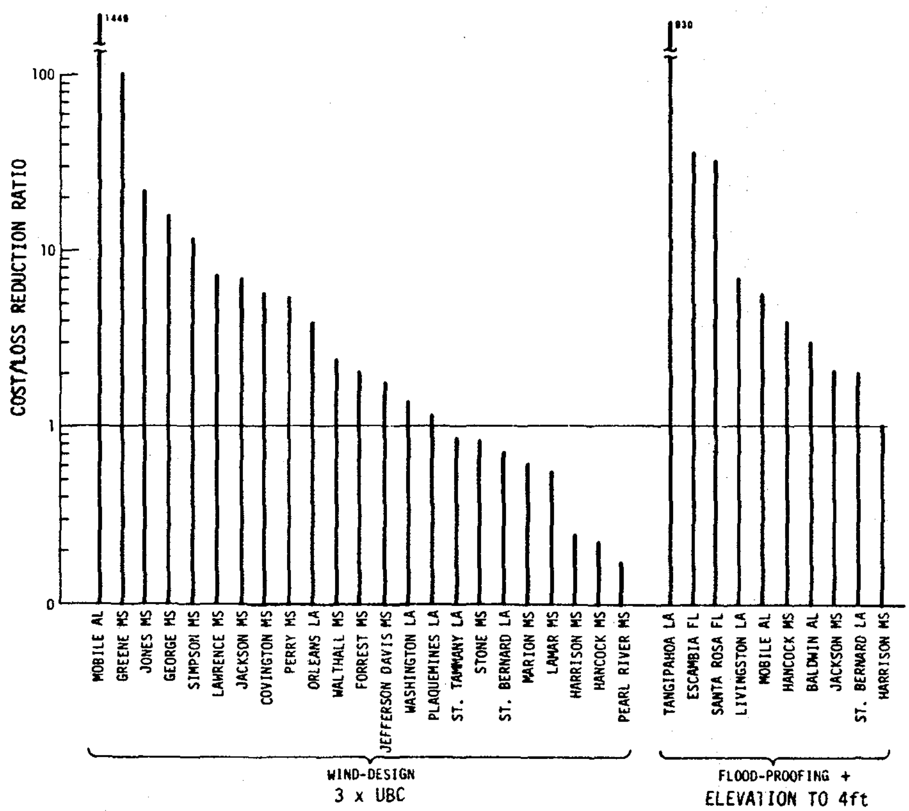


Figure 6-18. Cost/Loss Reduction Ratios

As shown in Table 6-7, the two structural mitigations (wind-design and flood-proofing) will result in loss reduction of 58% to 63% in mortality, unemployment, and homelessness. These figures approximate overall percent dollar loss reductions.

TOTAL ECONOMIC LOSS	$ 5,861		
TOTAL LOSS WITH MITIGATION	2,480		
TOTAL SAVINGS	$ 3,381	MILLION	- 58%
OVERALL C/S RATIO 1.74			
TOTAL UNEMPLOYMENT (PERSON/YRS.)	67,732		
TOTAL UNEMPLOYMENT WITH MITIGATION	24,840		
TOTAL UNEMPLOYMENT SAVED	42,892	PERSON-YEARS	- 63%
TOTAL HOMELESSNESS (PERSON/YRS)	63,543		
TOTAL HOMELESSNESS WITH MITIGATION	24,909		
TOTAL HOMELESSNESS SAVED	38,634	PERSON-YEARS	- 61%
TOTAL NUMBER OF EXPECTED DEATHS	642		
TOTAL NUMBER OF EXPECTED DEATHS WITH MITIGATION	262		
TOTAL REDUCTION IN DEATHS	380	LIVES	- 59%
OVERALL PER CAPITA INCOME LOSS	$ 2,510		
OVERALL PER CAPITA INCOME LOSS WITH MITIGATION	1,062		
OVERALL PER CAPITA INCOME LOSS SAVED .	$ 1,448	DOLLARS	- 58%

Table 6-7. Hurricane Camille Total Impact Area Mitigation Summary Flood-proofing and Wind-design Loss Reduction (Year 2000)

Loss Reductions From Area-structural Mitigation Measures

Loss reductions for the 100-year storm sea wall and the "no growth" measures are shown in Table 6-8. It is apparent neither of these measures would be as cost-feasible as flood-proofing (considering savings alone). Loss reduction from the 50-year floodplain mitigation is relatively modest: an estimated 8%, compared to 35% for the 100-year storm sea wall and 47.5% for flood-proofing.

	LOSSES WITHOUT MITIGATION (MILLIONS OF DOLLARS)	LOSSES WITH MITIGATION (MILLIONS OF DOLLARS)	SAVINGS (MILLIONS OF DOLLARS)	SAVINGS (PERCENT)
FLOOD-PROOFING	790	415	375	47.5
100-YR STORM SEAWALL	790	513	277	35.1
NO GROWTH ON 50 YR FLOOD PLAIN	790	727	63	8.0

Table 6-8. Building Loss Reductions From Area-structural Mitigation Measures

Insurance Comparisons

As noted earlier, cost of the two structural mitigations is estimated at $255 per year per capita. This figure is equal to 1.3% of the total economic value at risk, and therefore, might be considered a form of insurance, i.e., spending money to save money as opposed to spending money to redistribute losses. In these terms, the cost does not appear to be out of line with current costs for hurricane insurance in Gulf coast states, or with earthquake insurance in California.

The San Francisco Earthquake of 1906 occurred on April 18, at approximately 5:13 AM. The principal quake had a duration of one minute, five seconds and was followed by 30 or more minor tremors before 7:00 AM. The epicenter was about ten miles from the center of downtown San Francisco - near Point Reyes. The magnitude was recorded at 8.3, one of the highest ever measured in California. Maximum intensities ranged from IX to XI MMI. Figure 6-19 shows the intensities in various counties. Each county was assigned the intensity that was recorded at the county seat, utilizing a computer-generated intensity map of the area [See Figure 6-20]. Figure 6-21 shows the placement of the county seats.

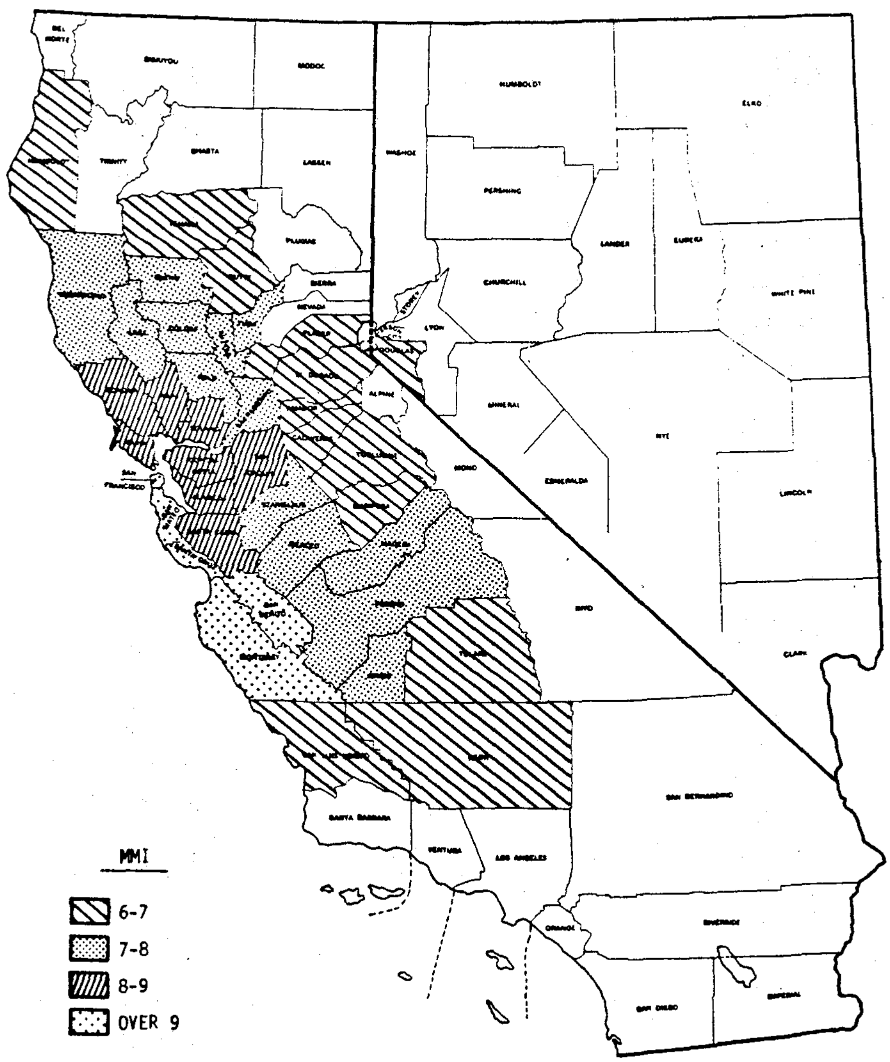


Figure 6-19. Intensities of Counties as Recorded in County Seats of the Thirty-nine Counties Used in San Francisco Earthquake Scenario

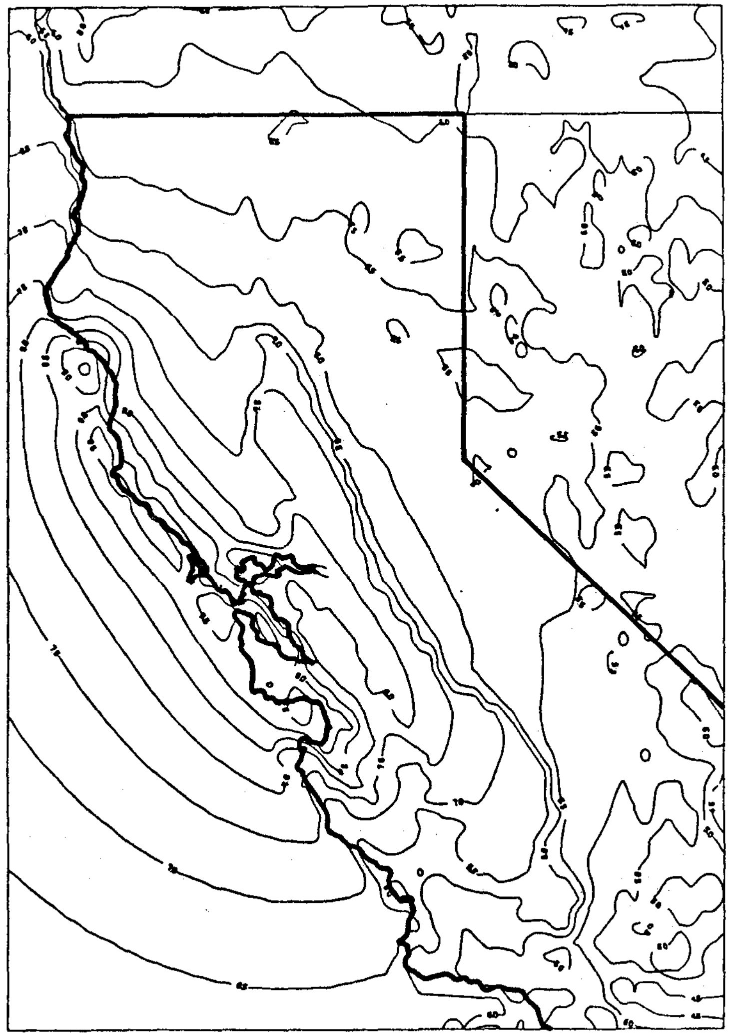


Figure 6-20. San Francisco Scenario Intensities Due to an M=8.25 Shock

Figure 6-21. County Seats of the Thirty-nine Counties in San Francisco Scenario

Seismologists assume that this earthquake resulted from an accumulation of stresses which ordinarily would have been relieved by smaller movements [Gilbert, et.al, 1907 and Iacopi, 1971]. Fault movement ripped the surface for almost 200 miles, the longest surface rupture caused by a single fault movement during recorded history. Horizontal displacement of 15-to-20 feet occurred; it was later found that this was common to the San Andreas fault. Before this time, earth movements were thought to be predominantly vertical. Figure 6-22 presents a graphic display of the major fault system in California, including the San Andreas fault.

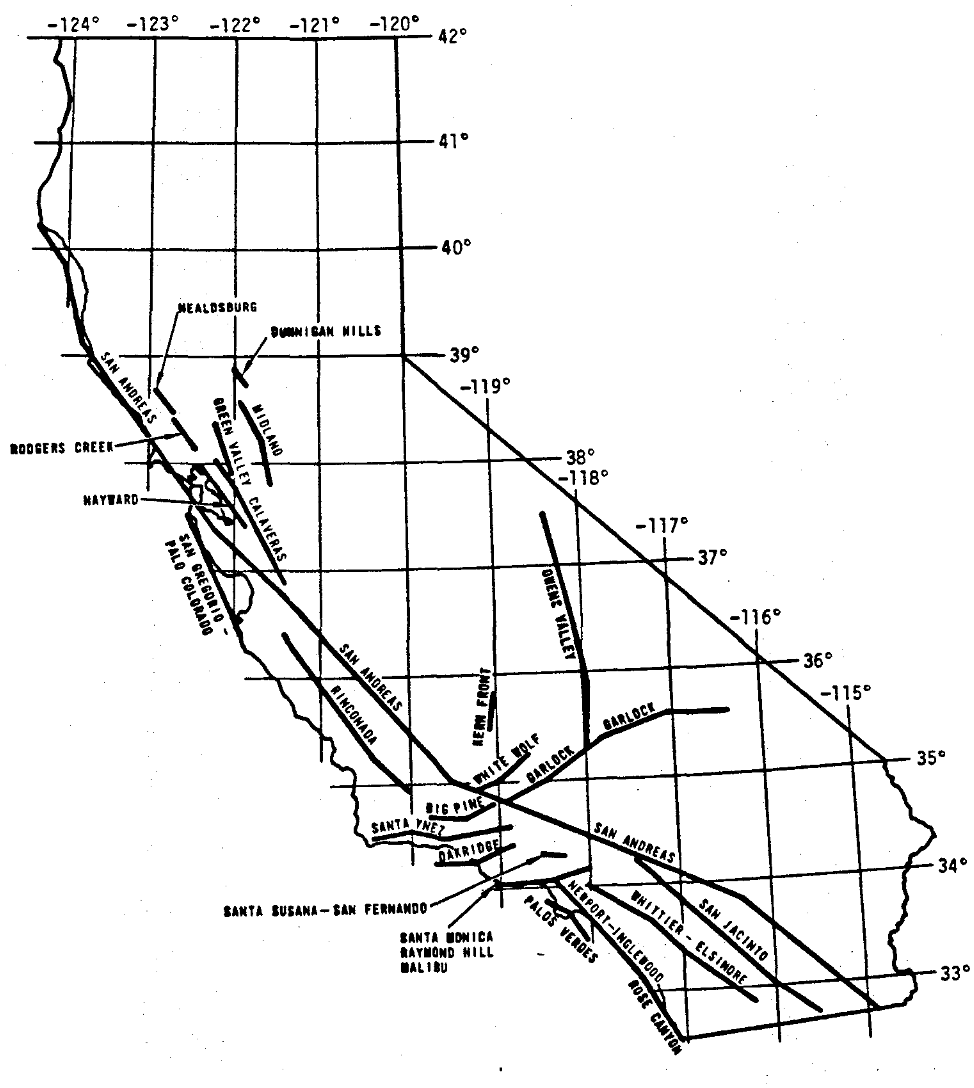


Figure 6-22. California Fault Lines

Three days after the earthquake, 2,593 acres had burned, destroying 490 city blocks completely and 32 others partially. Three hundred fourteen of these acres constituted the congested district of the city. A fifty-mile wide zone of destruction was produced which extended 150-to-200 miles in either direction from San Francisco. This zone began at Point Arena, went south to Hollister and included San Francisco Bay, Russian River and the Sonora, Santa Clara and Salinas valleys.

Over 700 people died in the earthquake and fires that followed. Four hundred million dollars of property damage was recorded, two hundred fifty million of which was in San Francisco. The hardest hit area was from San Jose to Santa Rosa [Iacopi, 1971]. Over 200,000 people were left homeless. Loss of life was low, however, due to the time of day that the earthquake occurred. Most people were sleeping, many in frame houses. If the earthquake had occurred four or five hours later when people were at work, in school, or otherwise actively occupied, many more could have died.

The exact number of deaths is unknown since many were buried very quickly and official records were not kept. Many structures were completely consumed by fire. One source claims that 112 patients at Agnew State Hospital perished due to the flimsily-constructed building; sixty-one people died in Santa Rosa and nineteen in San Jose. Outside of San Francisco, there were 189 known deaths [Richter, 1958].

The buildings hardest hit were those on filled ground. It was difficult to separate the earthquake and fire damage, but estimates attribute about twenty percent of the damage to earthquake and the rest to fire. The water supply was crippled by breaks in the distributing mains within the city limits, which led to failure to control the fire, rather than to a lack of water coming into San Francisco [Iacopi, 1971].

Defined 39-County Impact Area

This scenario repeats the original event, but is limited to those counties whose county seats experienced a MMI of 6 or greater in the original event. Table 6-9 shows the projected population distribution of these counties (by intensity) for the year 2000.

MMI 9 and over	20.8%	MMI 8 to 8.9	46.2%
Monterey San Benito San Francisco San Mateo Santa Cruz		Alameda Contra Costa Marin Napa San Joaquin Santa Clara Solano Sonoma	
MMI 7 to 7.9	**21.2%**	**MMI 6 to 6.9**	**11.8%**
Colusa Fresno Glenn Kings Lake Madera Mendocino Merced Sacramento Stanislaus Sutter Yolo Yuba		Amador Butte Calaveras El Dorado Humbolt Kern Mariposa Placer San Luis Obispo Tehama Tulare Tuolumne Douglas, NV	

Table 6-9. Percentage of Population Distribution by Modified Mercalli Intensities (Year 2000)

Under the scenario, principal damage will occur near the coast along the San Andreas fault. Monterey County, for example, was included because Salinas (the county seat) is at the uppermost part and on the fault line. In Table 6-10, population and per capita income for the impacted area are projected for the year 2000. All values are expressed in 1970 dollars. Income figures in the 39 counties affected by the scenario earthquake vary greatly, from a projected high per capita income of $11,060 in Marin County to a low of $5,776 in Kings County. Total population for the 39 counties in the year 2000 is projected to be approximately 12,537,000 persons, showing an increase of 55% over the 1970 population of 8,079,660. Average per capita income also is projected to increase 111% during that period.

Total economic value of the buildings in the 39-county area is estimated at approximately $236 billion in the year 2000. This value is equivalent to almost $18,900 per capita, as an average value for the area.

COUNTY	POPULATION		PER CAPITA INCOME (1970 DOLLARS)	
	YEAR 1970	YEAR 2000	YEAR 1970	YEAR 2000
Alameda	1,073,184	1,707,436	3,914	8,541
Amador	11,821	15,935	3,162	7,317
Butte	101,969	137,454	2,942	6,767
Calaveras	13,585	18,313	3,228	7,470
Colusa	12,430	16,756	3,421	7,869
Contra Costa	555,805	884,286	4,192	9,148
El Dorado	43,833	59,087	3,472	7,986
Fresno	413,329	657,606	2,952	6,782
Glenn	17,521	23,618	2,961	6,811
Humbolt	99,692	114,487	3,142	7,397
Kern	329,271	523,870	3,017	6,932
Kings	66,717	89,935	2,514	5,776
Lake	19,548	26,351	2,931	6,395
Madera	41,519	55,968	2,630	6,042
Marin	206,758	328,952	5,069	11,060
Mariposa	6,015	8,108	2,957	6,844
Mendocino	51,101	68,884	3,070	6,700
Merced	104,629	141,040	2,621	6,064
Monterey	247,450	393,693	3,317	7,237
Napa	77,632	123,513	3,345	7,695
Sacramento	634,190	1,008,996	3,609	8,302
San Benito	18,226	24,569	2,941	6,418
San Francisco	715,674	1,138,637	4,475	9,764
San Joaquin	289,564	460,696	3,208	7,424
San Luis Obispo	105,690	142,964	3,014	6,759
San Mateo	556,601	885,552	4,815	10,506
Santa Clara	1,066,421	1,696,676	4,063	8,866
Santa Cruz	123,790	166,869	3,363	7,339
Solano	171,815	273,358	3,268	7,131
Sonoma	204,885	325,972	3,253	7,099
Stanislaus	194,506	309,459	3,063	7,089
Sutter	41,935	56,528	3,247	7,470
Tehama	29,517	39,789	2,977	7,267
Tulare	188,322	253,858	2,665	6,123
Tuolumne	22,169	29,884	3,186	7,373
Yolo	91,788	146,035	3,182	7,320
Yuba	44,736	60,304	2,521	5,800
Douglas, NV	6,882	7,914	4,508	9,888
	TOTAL		AVERAGE	
	8,079,660	12,536,593	3,942	8,320

Source: County and City Data Book, U.S. Dept. of Commerce, 1972; and Obers Series E Projections, U.S. Water Resources Council, 1974

Table 6-10. Population and Per Capita Income for Thirty-nine Earthquake Scenario Counties, Years 1970, 2000.

Economic Loss Without Mitigation

Summary Losses (1906 versus 2000)

Reported losses from 1906 vary with the authors and are complicated by the inclusion of losses due to fire. However, the following figures seem to be a reasonable compromise: approximately 700 deaths, 200,000 people left homeless, and damage in the range of $400 million to property. The numbers available of those injured are too variable and vague to support an estimate.

Projected losses for the scenario years 1970 and 2000, both economic and non-economic, are shown in Figure 6-23. Non-economic losses will be noticed more in those counties with the highest intensities. The greatest unemployment is found in San Francisco, San Mateo and Santa Clara -- over 3000 per county in the year 2000. Also, over 500 deaths might be expected in San Francisco county alone. Many counties will not suffer non-economic losses. These counties are generally the ones with MMI's in the range of 6 to 7--further away from the epicenter of the earthquake. Thus, care must be taken in assessing the impact of total losses from such a scenario in that the greater losses are concentrated in a relatively small area.

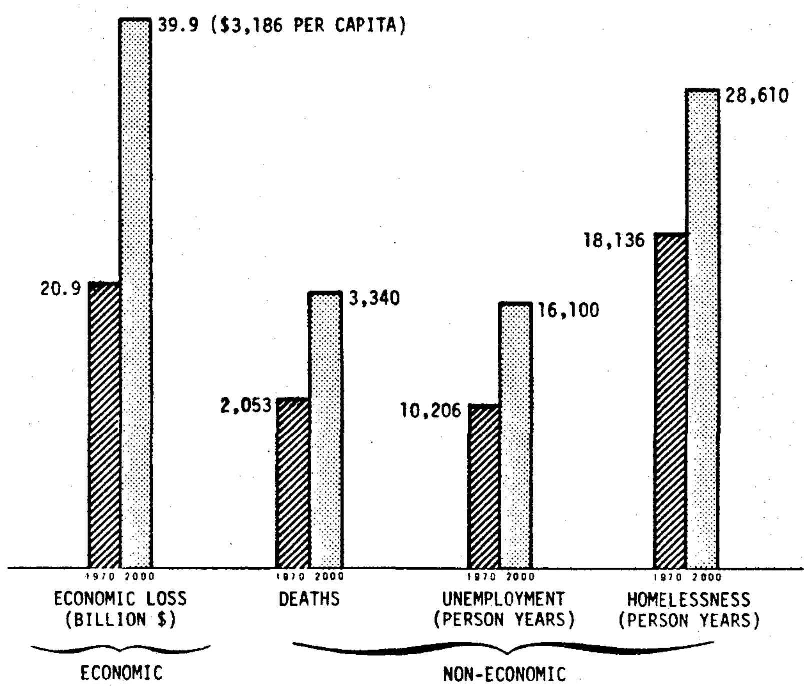


Figure 6-23. Loss Comparisons - 1970 and 2000 Scenario Without Mitigations

Per Capita Economic Loss

Economic loss in the year 1970 is projected to be over 21 billion and in the year 2000 to be almost twice that much. These estimates yield per capita losses of $2584 in 1970 and $3186 in the year 2000. However, losses vary greatly from county to county. In dollar amounts, the greatest losses will occur in San Mateo ($7555 per capita) and Santa Cruz ($7044 per capita). Figure 6-24 shows the variance. Table 6-11 shows that half the counties will experience a loss of under $1000--less than one-third the average figure. Because of high exposure values and concentrated population, only nine counties will experience losses in excess of the average, four of these over $5500 per capita.

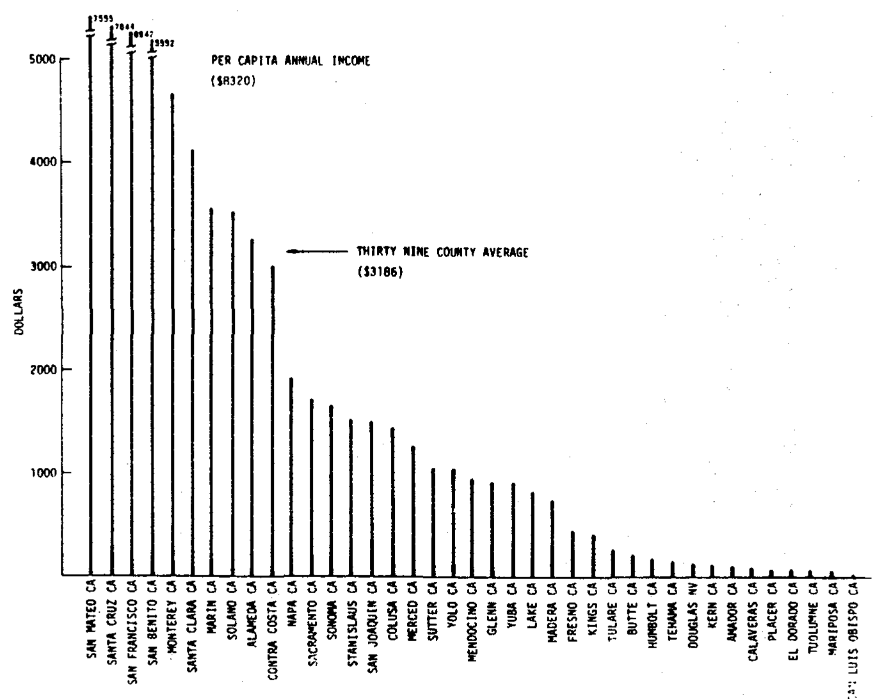


Figure 6-24. Per Capita Economic Loss Comparisons for Thirty-nine Counties Due to the San Francisco Earthquake (Year 2000)

ECONOMIC LOSS	NUMBER OF COUNTIES	PERCENT OF TOTAL
UNDER $ 100	7	17.9
100 - 499	8	20.5
500 - 999	5	12.8
1,000 - 1,999	9	23.1
2,000 - 2,999	0	0.0
3,000 - 3,999	4	10.3
4,000 - 4,999	2	5.1
5,000 - 10,000	4	10.3
TOTAL	39	100.0

MEDIAN $ 913
AVERAGE $3186

Table 6-11. Per Capita Economic Loss Without Mitigation, Distribution by County (1970$ - Year 2000)

Projected economic loss due to a San Francisco earthquake in the year 2000, without new mitigation measures, would be close to 40 billion dollars in the 39-county area. This is equivalent to about 38.3% of the per capita income in the area (projected to be $8320 in 1970 constant dollars). Figure 6-25 and Table 6-12 show the variance in losses among the counties as a percentage of per capita income.

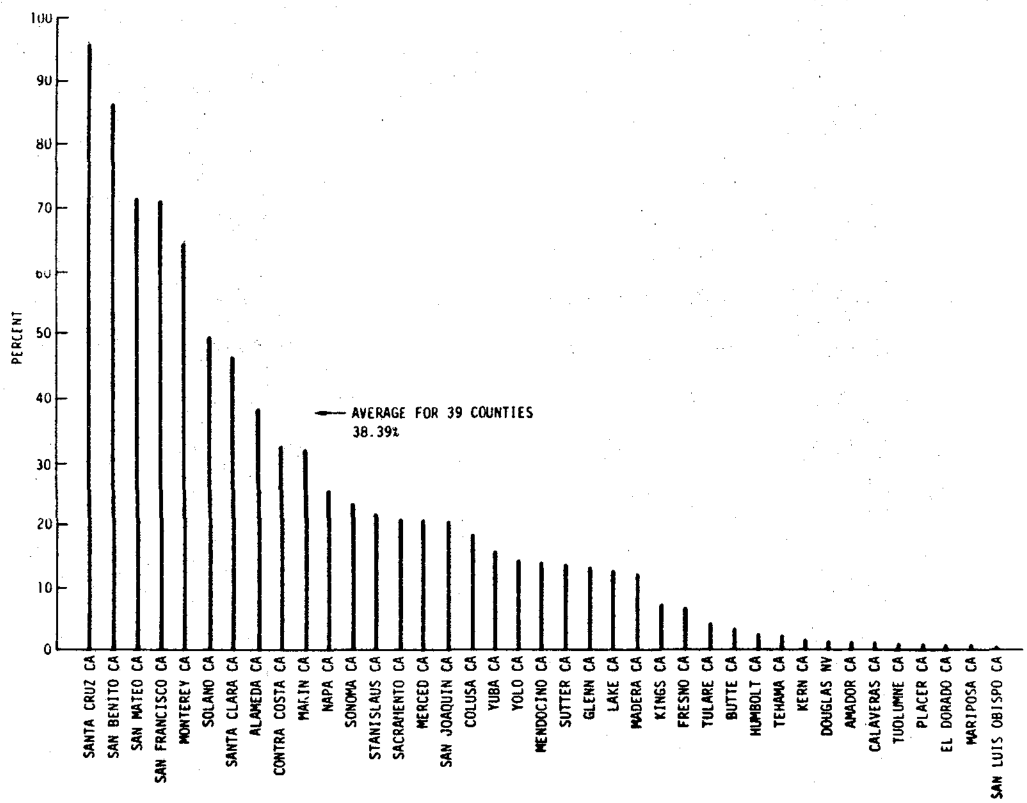


Figure 6-25. Per Capita Economic Loss Comparisons as Percent of Per Capita Annual Income (Without Mitigation - Year 2000)

PERCENT OF INCOME	NUMBER OF COUNTIES	PERCENT OF TOTAL
UNDER 1.0%	5	12.8
1.0% - 4.9%	8	20.5
5.0% - 9.9%	2	5.1
10.0% - 24.9%	13	33.4
25.0% - 49.9%	6	15.4
50.0% - 100.0%	5	12.8
TOTAL	39	100.0

MEDIAN 14.0%
AVERAGE 38.3%

Table 6-12. Per Capita Economic Loss as a Percent of Per Capita Income (Without Mitigation - Year 2000)

Distribution of Economic Loss

In the 39-county area, approximately 45.5% of the $39.9 billion loss represents the value of building damage, the balance representing losses of building contents, except for food. Food would be considered part of building contents only if the damage were to a food establishment. Supplier loss and income loss are also included in the 54.5%.

Economic Loss Distribution by Family Income Group

Table 6-13 shows the percentage of the population in different income categories for the 39 counties. The loss is also distributed using the same percentage distribution by county as that used for the population. As can be seen from the table, the higher income groups are experiencing a slightly greater loss than the lower income groups; however, the percentage is very close. Actually, no single income group appears to suffer an extraordinary loss.

INCOME CATEGORIES	POPULATION DISTRIBUTION (PERCENT)	LOSS DISTRIBUTION (PERCENT)	DIFFERENCE (PERCENT)
1. LESS THAN $3000 ANNUAL FAMILY INCOME	8.4	7.4	(1.0)
2. $ 3000 - $ 4999	9.0	7.5	(1.5)
3. 5000 - 6999	10.2	9.1	(1.1)
4. 7000 - 9999	18.1	17.1	(1.0)
5. 10000 - 14999	28.0	28.9	.9
6. 15000 - 24999	20.5	23.1	2.6
7. 25000 AND OVER	5.8	6.9	1.1
TOTAL	100.0	100.0	0

Table 6-13. Population and Loss Distribution, San Francisco Earthquake Scenario (Year 2000)

Non-economic Losses

Only three types of non-economic losses have been considered: mortality, unemployment, and homelessness. Consideration of other social factors was beyond the scope of this analysis. However, specific stakeholder impacts from general hazard and mitigation impacts are examined in a later chapter.

Mortality

Mortality figures are projected at 2050 for the year 1970, and 3340 for the year 2000. This means one in every 3750 persons may possibly die as a result of the earthquake in the year 2000. It is estimated that between 450 and 700 persons died as a result of the 1906 earthquake. It must be noted that the time of day when the event occurs is extremely important in estimating the number of deaths which may occur. For example, in a NOAA [1972] study of earthquake losses for San Francisco, it is estimated that a change in the time of occurrence from early morning hours to mid-afternoon hours would result in an increase in deaths by a factor of 4. Thus, if San Francisco Earthquake II were to occur in mid-afternoon, it is reasonable to expect life loss to be nearly 12,000. Moreover, NOAA also estimates an increase in hospitalized injuries from 10,800 to 40,360 for the same shift in time of occurrence.

Unemployment

Projections of unemployment due to the earthquake are unimpressive: 10,200 person-years in 1970, and 16,100 person-years in 2000. In a population of 12.5 million, normal unemployment at 5% would be about 250,000 persons per year.

Homelessness

As with unemployment, the projected figures are low: about 18,000 person-years in 1970, and almost 29,000 person-years in 2000. These figures may be viewed in different ways: (1) that almost 29,000 people will be homeless for a year--which is unlikely, or (2) that over 343,000 people will be homeless for an average of 30 days--a more realistic conclusion. Thus, 2.7 percent of the people in the affected area will be separated from their homes for one month in the year 2000.

Possible Mitigation Measures and Costs of Their Implementation

The scenario mitigation utilized to reduce damage was one which involves an upward adjustment in the lateral force specifications contained in the 1973 Uniform Building Code for Zone 3 structures. Present design parameters require earthquake resistance above magnitude 6 (based on a Modified Mercalli Intensity scale).

Mitigation measures for this scenario require increasing this strength requirement by two for all new construction starting in 1980.

Because it is estimated that existing construction will represent about 40% of the total value at risk in the year 2000 ($94.1 billion of $236.1 billion), and because the study counties which will manifest growth are not currently highly developed, mitigations were not established for pre-1980 buildings. Figure 6-26 shows cost of the mitigations as applied to new construction as $33.7 billion; a sum which would be expended over a 20-year period (1980 - 2000). At 10% interest, annual expenditures would total $3.37 billion. This amount when spread over the projected population comes to $269 per person [See Figure 6-26].

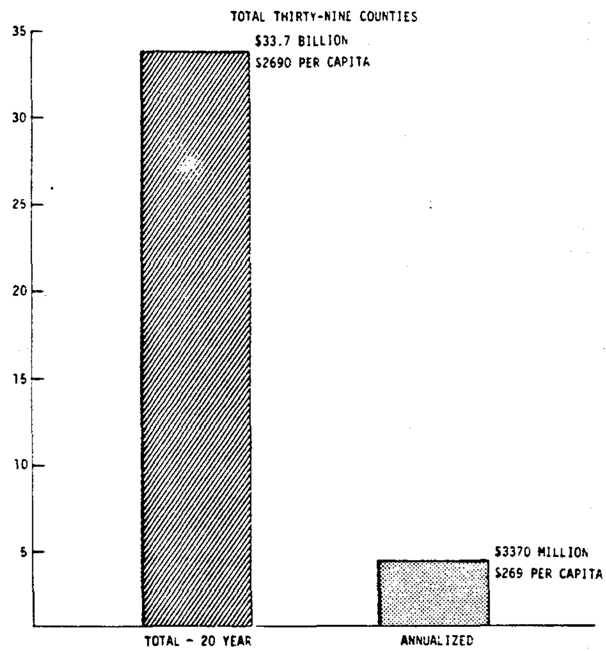


Figure 6-26. Costs of Mitigation (Structure Only) for San Francisco Earthquake Scenario (Year 2000)

Per Capita Costs of Mitigation

Figure 6-27 shows annual earthquake mitigation costs of $269 per person. The total estimated cost of mitigation--$33.7 billion--is approximately 14.3% of total building value at risk ($236 billion) in the year 2000. Annual mitigation cost of approximately $269 per person constitutes 3.2% of average per capita income.

The mitigation cost of $269 mentioned above compares unfavorably with the "normal" costs of providing municipal services: approximately $170 per capita.

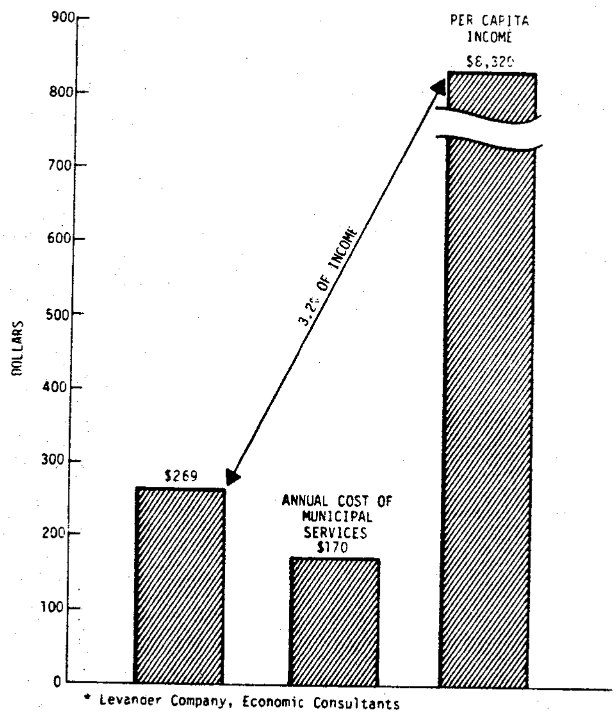


Figure 6-27. Annualized Costs of Mitigation (Structural Only) Per Capita Comparisons, Year 2000

Loss Reduction From Structural Mitigation

Expected dollar losses without new mitigations from a reoccurrence of the San Francisco Earthquake in the year 2000 would total $39,943 million. By increasing building standards, losses could be reduced to $28,595 million; thus producing a savings of $11,348 million, or 28% [See Table 6-14].

Loss Without Mitigation	(millions)	$ 39,943
Loss With Mitigation	(millions)	$ 28,595
Savings	(millions)	$ 11,348
Percent		28%

Table 6-14. San Francisco Earthquake Building Loss Reductions, after Implementation of Structural Mitigation in the Year 1980, Year 2000.

The ratio between cost of mitigation and gross loss reduction is 2.97 [presented graphically in Figure 6-28]. Because projected costs are significantly higher than expected loss reduction, the mitigation requiring increasing the design lateral force requirements of the UBC by a factor of 2 for Zone 3 would seem to be economically disadvantageous to the vulnerable area. This conclusion is corroborated by Figure 6-29, which gives a cost/loss reduction ratio for each affected county. None is below one, which means that the cost is higher than the expected loss reduction.

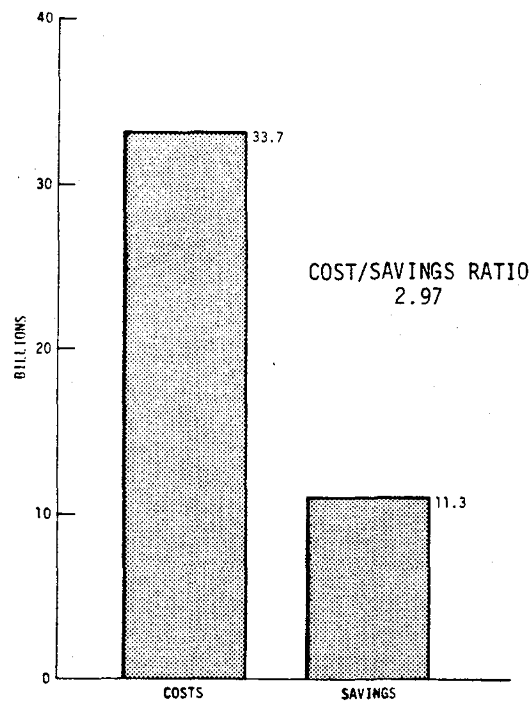


Figure 6-28. Mitigation Costs and Savings for San Francisco Earthquake Scenario, Year 2000.

Insurance Comparisons

Constructing buildings to meet the more stringent code is estimated to cost $269 per person per year--1.4% of the estimated $18,836 per capita at-risk. This appears to be approximately the same as that for earthquake insurance available in California at the present time. Thus, the purchase of insurance at a cost of approximately the same as the annualized cost of the mitigation has an interesting public policy implication. Specifically, an insurance purchase is an individual choice selected by an individual for the purpose of reducing his personal risk of loss; whereas a structural mitigation embodied in a building code is a public choice requiring compliance by all. When considering a cost/loss reduction ratio of greater than 1 for all affected counties, it appears that insurance may be the best approach to individual loss mitigation.

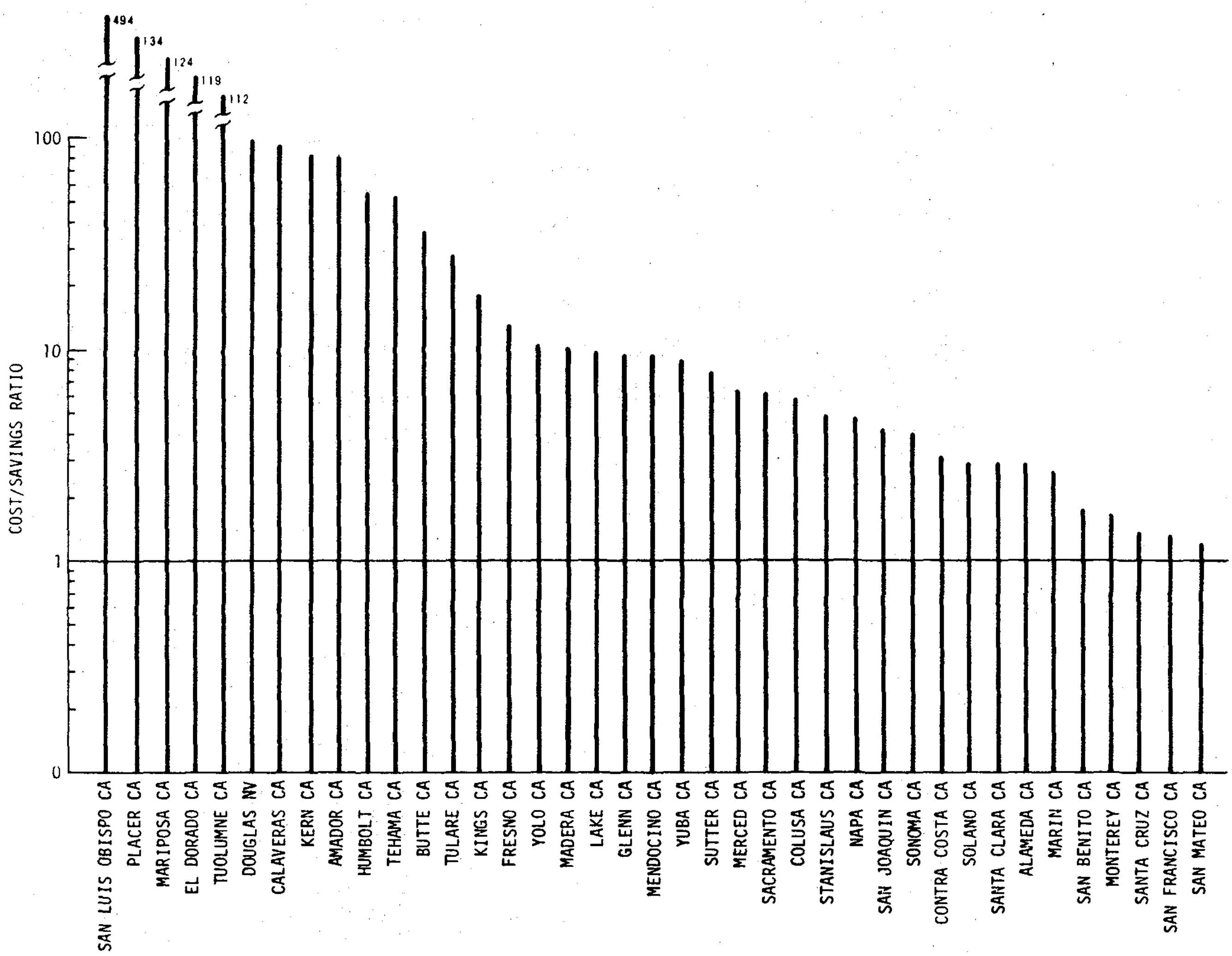


Figure 6-29. Cost/Savings Ratios for San Francisco Earthquake Scenario (With Mitigation - Year 2000)

Other Scenarios

During the course of this project other scenarios also were prepared. Thus the computer models predict that Cook County, Illinois would experience $2100 million damage in 1980 and $3500 million in 2000 from a downtown center strike of a Fugita Level 4 tornado [Hart, 1976]; that a repeat of the riverine flooding associated with Hurricane Agnes (1972) conditions under projected actual conditions of flood protection in 2000 in multi-state region #2 would produce damage to more than 151,000 structures and an episodic building damage loss of $1008 million [Lee, et al, 1976].

Other researchers also have produced catastrophic loss scenarios for a variety of hazards and have predicted similar high episodic losses. Thus, White and Haas [1975] have prepared qualitative scenarios for the following conditions: 1) a major hurricane strike on Miami; 2) a riverine flood in Boulder, Colorado; and 3) a repetition of the San Francisco earthquake. The National Oceanic and Atmospheric Administration [1972, 1973, 1974] has prepared, for the Department of Housing and Urban Development, quantitatively-oriented scenarios showing the consequences of major earthquakes in San Francisco, Los Angeles, Salt Lake City, and Seattle. The Los Angeles scenario predicts 2790 (2:30 AM) to 12,385 (4:30 PM) deaths from an 8.3 magnitude earthquake on the San Andreas fault and 4090 (2:30 PM) to 20,728 (4:30 PM) deaths from a 7.5 magnitude earthquake on the Newport-Inglewood fault. Dam ruptures could add 7520 deaths to the San Andreas quake and 2200 deaths to the Newport-Inglewood quake, according to NOAA. Thus, a major quake at the appropriate hour on one of the Los Angeles area fault lines could - according to NOAA - cause up to 25,000 deaths. Roughly comparable results were shown for San Francisco.

Although no modern scenario writer has predicted hurricanes/storm surge deaths at a <u>rate</u> recorded during the 1900 Galveston disaster (6000 deaths out of a population of approximately 60,000) it does not stretch one's imagination to assume that 25,000 deaths could result from a "great" hurricane strike on a major Gulf or Atlantic coast metropolis.

Conclusions

1. Major catastrophes associated with large losses of life and property may be expected in high hazard areas of the United States, with particular reference to the hurricane and storm surge zones of the Gulf coast and Atlantic, and the major earthquake-prone metropolitan areas of the United States.

In terms of life loss, the largest U.S. natural catastrophe of this century was the Galveston Hurricane and coastal flood of 1900 which claimed the lives of approximately 10% of the Galveston Island population and therefore produced an episodic death rate of 1000 and 100,000 population. In contrast, this study suggests that an exact repeat of the great San Francisco Earthquake in 2000 would produce an episodic death rate of approximately 26.7 persons per 100,000 population and that an exact repeat of Hurricane Camille would produce a death rate of approximately 27.8 per 100,000 population, each rate relating to the total impact area of the occurrence. If a mid-day or late afternoon recurrence of the San Francisco Earthquake were to take place, death rates would increase by a factor of 4 to 5. Indeed, an even greater escalation could be expected were major potentially-hazardous facilities to be damaged or ruptured and if wide-spread failure of dams and reservoirs in an earthquake-prone city such as San Francisco were to take place. Similarly, if a hurricane of Camille's strength were to strike full force on the central city of a major metropolitan area the death rates could easily be increased by a factor of 5 to 10, or more. Even with the advanced warning systems and evacuation plans that characterize the state of today's disaster preparedness, it is nonetheless clear that a substantial fraction of the population of hurricane-prone coastal communities do not respond to these warnings and do not evacuate themselves from hazard areas [Miletti, Drabek and Haas, 1975].

Chance, alone, has influenced the fact that no major U.S. city in this century has been struck - full force - with a hurricane of the magnitude of Camille or the devastating impact of the 1900 Galveston occurrence. Chance, alone, has influenced the fact that no earthquake of the highest magnitude that has occurred in the U.S. in the past 150 years has yet occurred in a large earthquake-prone metropolitan area. Only chance, therefore, has thus far prevented in the current century the exposure of a large metropolitan-scale population to the kind of devastating, high magnitude, natural hazard occurrence which can be expected to occur once-or-more in a country of this size and geographic diversity over the period of 100-to-150 years.

When such an exposure does occur, single episode losses in excess of $40 billion can be expected and life loss approaching - or exceeding - 23,000 to 25,000 persons can conservatively be predicted.

2. Even if the occurrence of a Camille - magnitude hurricane or a "great" San Francisco Earthquake is assigned a probability of "one" for a major impact area, the national application of the "most effective" mitigation or reduction of losses from such single episodes does not appear to be cost-feasible.

At a 6.1 per cent interest rate, 4-foot flood proofing of new structures in surge-prone areas and imposition of wind resistance standards equal to 3 x UBC on new structures produce annual amortized mitigation costs which are nearly double the annual, non-discounted value of the anticipated single-episode loss reductions. Also, the annual amortized mitigation costs equal $255 per capita, about 4.0 per cent of per capita income, and exceed - by 50% - the normal annual per capita costs of municipal services.

In respect to new structures in an area subject to a "great San Francisco - magnitude earthquake," a doubling of the lateral force specifications contained in the 1973 Uniform Building Code for earthquake Zone 3 structures produces annual amortized mitigation costs (at 6.1%) of $269, a value which is equal to 3.2% of per capita income and is more than 50% above the annual per capita costs of all municipal services. These annual costs are in excess of expected annual loss reductions by a factor of 3.

This conclusion does not mean to suggest that only economic criteria be employed in the mitigation decision-making process; but does suggest that decisions by higher levels of government may suppress local determination regarding the issue of making the severity of the regulation conform to the severity of the risk. Specifically, the potential for a large episodic loss, both economic and social, exists in many areas of the country; all areas are not uniformly susceptible nor will all communities place the same value on a given level of susceptibility. Accordingly, policy makers may wish to preserve the opportunity for local assessment of risk and for differential weighting of tests of cost feasibility.

Chapter Seven

PAST AND PRESENT PUBLIC APPROACHES TO THE MANAGEMENT OF NATURAL HAZARDS

Introduction and Summary

Substantial annual investments are being made each year by federal, state, and local governments to deal with natural hazards. These investments are aimed at a range of objectives, including those intended to protect communities from hazard occurrences, to force the use of loss-reducing technologies by builders and building owners, to reduce and spread the losses sustained by individuals exposed to hazards, to identify and promote the avoidance of high hazard areas, to warn exposed persons of impending hazards, and those related to advancements, in human understanding concerning hazard occurrences and possible mitigations.

Taxonomy of Natural Hazard Mitigation Policies

Public efforts to reduce the losses and to ameliorate the pain, suffering, and inconvenience produced by human and property exposure to natural hazards will inevitably involve some focus on the role of governmental policies and programs in this field. The range of possible policies and actions which may be implemented by the various levels of government may be grouped into several major classes, including the following:

1. Action-forcing policies: those intended to force loss-reducing activities by various units and jurisdictions of government.

2. Attention-focusing policies: those intended to stimulate citizen, group, and governmental interest in losses produced by natural hazards and to promote voluntary state, local, and private action to reduce such losses.

3. Disaster recovery policies: those intended to assist personal, familial, neighborhood, community, and state recovery from the damages sustained as a result of exposure to a natural hazard.

4. Technology development policies: those focused on development of new knowledge concerning the subject and on the information and technology necessary to support the making and implementation of hazard-mitigating policies.

5. Technology transfer policies: those which are focused on transfer of knowledge to consumers, governments and others; and on the development of user capacity to make effective use of that knowledge, both in the long term (as in hazard analysis programs) and in the short term (disaster warnings).

6. Regulatory policies: those which involve regulating the decisions and behaviors of private parties and other governmental entities to bring about the reduction of losses associated with exposure to natural hazards. Such policies may involve avoidance, building strengthening, site preparation, and other methods.

7. Investment and cost allocation policies: policies concerned with the acquisition and allocation of resources necessary to sustain the activities described above and below. Such policies determine how much will be spent, when, for what purpose, where, and at whose expense.

8. System management policies: intended to fix responsibilities, to specify the means to be employed, and to define the restrictions to be met by hazard mitigation policies and programs.

9. System optimization policies: intended to assure that other policies in the set are compatible with system goals, effective, internally consistent with each other, and in consonance with other policies.

10. Direct action policies: authorizing direct governmental action to implement a policy, such as physical construction or removal of structures (buildings, levees, dams).

Each of the several classes of possible policies is functionally related to one or more of the other classes; any single type of policy may be described as belonging to more than one class; and each class is distinguished by its own set of goals or target public problems.

Federal Natural Hazard Legislation and Programs

Federal legislative responses to natural hazards have covered a broad spectrum, ranging from massive investments in area flood control facilities, through the operation of disaster warning systems, to extension of post-disaster assistance to loss-experiencing parties. Although numerous programs address problems posed by natural hazards as part of the broader mandate of an administering agency, specific natural hazard-related legislation has been limited. Major legislative actions specifically addressing natural hazards include:

Flood Control: Because riverine and coastal flooding has long been a source of natural disaster in densely-populated areas, the federal government has taken the responsibility for constructing major flood control works since 1936. The U.S. Army Corps of Engineers is the one dominant agency operating in this field. In addition, a Dam Inspection Act was passed in Congress in 1972 to initiate safety inspections of private dams as a preventive measure against floods. Also the Federal Flood Insurance Program has been used to stimulate implementation of floodplain avoidance and flood proofing measures by local units of government.

Disaster Relief: Federal disaster relief legislation was first enacted in 1950, and subsequently in 1966, 1969, 1970, and 1974. Once a disaster has occurred, a Presidential declaration renders the affected region eligible for special aid for relief and recovery. In addition, the designation as a natural disaster area makes the residents eligible for low-interest loans from the Small Business Administration and the Farmers Home Administration for the repair and rehabilitation of damaged structures.

Earthquakes: The signing into law of the Earthquake Hazards Reduction Act in October 1977 expanded funding for research into the prevention and mitigation of earthquake hazards. Previously, earthquakes had been addressed in disaster relief provisions, and funds had been appropriated to the National Science Foundation for the study of earthquake-prevention engineering ($8 million in fiscal 1974). This act represents the first broad federal mandate for earthquake mitigation efforts.

In addition, federal legislation has established a national coastal zone management program, a program of flood insurance, and several mortgage-subsidy programs which empower one or more federal agencies to specify the structural quality of buildings qualifying for a mortgage. Other programs have funded research, hazard area mapping, and hazard-warning service. Still other programs have authorized training, education, and public information programs which could - in part - be targeted on natural hazard management subjects.

In addition to insurance, disaster relief, inspection programs and land use management programs, the federal government has moved into the area of establishing structural design requirements for mobile homes. Specifically, mobile homes, in order to obtain the designation of "hurricane-resistive" must be designed to withstand horizontal wind loads of not less than 25 pounds per-square-foot (psf) and a net uplift of not less than 15 psf. HUD may establish more stringent requirements for exposures in the coastal zone. [Federal Register, 1975]

Federal government hazards legislation of recent vintage includes the acts identified in Figure 7-1.

TITLE OF LEGISLATION	DATE ENACTED	LAW NUMBER	AGENCY	BUDGETS
1. DISASTER RELIEF ACT OF 1974	1974	PL 93-288	FEDERAL DISASTER ASSISTANCE ADMINISTRATION (FDAA)	$150,000,000 (fiscal 1978)
2. NATIONAL FLOOD INSURANCE ACT	1968	PL 90-448	HUD, FLOOD INSURANCE ADMINISTRATION	$ 91,000,000 (fiscal 1978)
3. FLOOD DISASTER PROTECTION ACT	1973	PL 93-234	HUD, FLOOD INSURANCE ADMINISTRATION	$ 91,000,000 (fiscal 1978)
4. NATIONAL DAM INSPECTION PROGRAM	1972	PL 92-367	ARMY, CORPS OF ENGINEERS	$ 15,000,000
5. EARTHQUAKE HAZARDS REDUCTION ACT	1977	PL 95-124	TO BE DESIGNATED BY THE PRESIDENT	$205,000,000
6. COASTAL ZONE MANAGEMENT ACT	1972	PL 92-583	DEPT. OF COMMERCE, NOAA	$ 27,438,000 (fiscal 1978)
7. MOBILE HOME CONSTRUCTION SAFETY STANDARDS ACT OF 1974	1974	PL 93-383	DEPT. OF HOUSING & URBAN DEVELOPMENT	$ 485,000 (fiscal 1978, est.)

Figure 7-1. Major National Legislation Related to Natural Hazards (1968-1977)

As shown in Figure 7-2, major natural hazard legislation by the federal government encompasses all ten policy types listed under the taxonomy of mitigation policies. Most frequently represented in federal legislation are technology transfer and attention-focusing policies, and only in the Corps of Engineers flood control activities is the federal government engaged in direct action without operating through other levels of government. The federal government is, however, engaged in direct action with respect to natural hazards as part of numerous other programs as discussed below. The Coastal Zone Management, National Flood Insurance Programs, and the Mobile Home Construction and Safety Standards Act are the only federal activities which involve action forcing policy.

LEGISLATION OR PROGRAM	TYPE OF POLICY									
	ACTION-FORCING	ATTENTION-FOCUSING	DISASTER RECOVERY	TECHNOLOGY DEVELOPMENT	TECHNOLOGY TRANSFER	REGULATORY	INVESTMENT AND COST ALLOCATION	SYSTEM MANAGEMENT	SYSTEM OPTIMIZATION	DIRECT ACTION
NATIONAL FLOOD INSURANCE PROGRAM	●	●	●		●	●	●	●		
NATIONAL DAM INSPECTION PROGRAM		●			●	●	●			
DISASTER RELIEF ACT OF 1974	●	●	●	●	●		●	●		
EARTHQUAKE HAZARDS REDUCTION ACT OF 1977		●	●	●	●			●	●	
FLOOD CONTROL WORKS (USCE)										●
COASTAL ZONE MANAGEMENT ACT	●	●		●	●	●		●	●	
MOBILE HOME CONSTRUCTION & SAFETY STANDARDS ACT OF 1974	●	●		●	●	●				●

Figure 7-2. Major Disaster-related Legislation by Policy Typology

Flood Hazard Legislation

Of the nine natural hazards examined in this study, riverine floods have received the greatest attention from the federal government. Legislation dealing with riverine floods has included: (1) The Flood Control Act of 1936, et. seq., (2) The National Flood Insurance Act of 1968, (3) The Flood Disaster Protection Act of 1973, and (4) The National Dam Inspection Act of 1972.

The first of these acts signalled the beginning of a massive federally-funded effort to reduce flood hazards through construction of dams, levees, floodway improvements, and other similar measures. The flood insurance and flood disaster protection acts signalled a shift in policy and a developing federal awareness that floodplain avoidance measures should be given a priority equal or exceeding the earlier commitment to structural approaches to the problem.

Flood Control Act of 1936, et. seq. (Administered by the United States Army Corps of Engineers). The Flood Control Act of 1936 established the Corps of Engineers as the primary agency for the construction of flood control works. This program has been expanded through numerous other legislative actions to become part of a broader responsibility now labelled by the Corps, "water resources development." Under this program, the Corps expended a total of $1.8 billion in fiscal 1974 and $2.1 billion in fiscal 1975 on rivers, harbors, and flood control. In this two-year period the Corps undertook 24 major new flood control projects, and it estimates savings from flood losses generated by its flood control works as $22.5 million during this same two-year period. The Corps estimates cumulative damages prevented by its flood control projects through June 1975 to be $59.5 billion, compared with a federal cost of $10.2 billion for those projects. During fiscal 1975, the Corps worked on constructing 62 flood control lakes in all parts of the United States, and topped out two dams under construction in California. Other projects were for local protection including levees, dikes, flood walls, diversion channels, channel alterations, and pumping and land treatment to protect a local area.

In addition, the Corps provides information, technical and planning assistance, and guidance to communities in identifying magnitude and extent of the flood hazard and in planning wise use of floodplains. The agency issues Floodplain Information Reports containing flood area maps, tabulations, hydraulic data, and narrative descriptions which include some flood history and estimates of the frequency of future floods. Non-structural alternatives also are part of the activities of the Corps, such as the acquisition of wetlands for natural storage areas and the development of recreation facilities in flood-prone lands. [U.S. Corps of Engineers, 1974 and 1975].

National Flood Insurance Act of 1968 [PL 90-448]; Title XIII of HUD legislation, enacted August 1, 1968, administered by the Flood Insurance Administration and the Secretary of the Department of Housing and Urban Development.

Although no federal action was implemented until 1968, the possibility of insurrance against flood hazard was considered after each major flood. Hurricanes and floods in California and the northeast in 1955 led to the enactment of the Federal Flood Insurance Act of 1956 [P.L. 1016, 84th Congress, 70 Stat. 1078], but because of disagreement with the insurance industry and doubts over the effectiveness of the proposals, funds were not appropriated.

The Alaska earthquake of 1964 and Hurricane Betsy in 1965 provided the final impetus for federally-subsidized flood insurance [U.S. Congress, 1966]. With rising concern over the losses from natural disasters and increasing federal funds necessary for relief of victims, and the limited success of local communities in managing their flood plains [Platt, 1976], the National Flood Insurance Act of 1968 [P.L. 90-448, Title XIII] was adopted. Through it, the federal government became involved with the land use planning process on non-public lands, in what the Administrator of the National Flood Insurance Program called the "first constructive land use bill in the Nation." [U.S. Congress, 1975]

The land use ramifications of flood insurance programs were recognized by the report to the President from HUD prior to passage of the 1968 Act. [U.S. Congress, 1966]. HUD believed the best long-run solution to be a shift in land use - from residential to industrial or to recreational, or simply as overflow land to help contain floods. In a city with long-range economic land use plans, substantial changes in land use could be made over time without severe hardship. HUD noted that zoning, building permits, extension of public services, and other public actions could provide guides to private investment which could work toward the same end. In HUD's view, the management of flood-prone areas went beyond flood insurance alone, but it suggested that flood insurance should be a facilitating force toward long-range land use policies.

Approximately seven percent of the land area of the United States is subject to flooding, and this land is under the jurisdiction of 17,000 local governmental units [Platt, 1976]. A United States Geological Survey study of 26 United States cities showed that over half their flood plain land, on the average, was developed at urban densities [Schneider and Goddard, 1974]. The USGS study [Table 7-1] illustrates the extent to which flood plains can cover large portions of urban areas; of the cities studied, an average of over sixteen percent of their area is within a flood plain. Ten percent of Chicago, about 132 square miles, is subject to flooding, and that area includes some of the most densely-developed portions of the city.

The increasing value of development in urban flood plains, plus continued urban expansion along rivers, as suggested in Table 7-1, corroborate Gilbert F. White's [1945] finding that to build dams and dikes without restraining further occupance of the flood plain was to invite greater losses upon the occurrence of a flood exceeding design limits.

Urbanized area	Flood plain		Developed	
	Area (sq.mi.)	Percent of urbanized area	Area (sq.mi.)	Percent of flood plain total
Asheville, NC	1.6	4.4	1.0	65.0
Boise, ID	2.5	8.5	2.1	84.0
Boston, MA	62.4	9.4	11.9	19.1
Charleston, SC	39.8	40.1	21.2	53.3
Chicago, IL	131.8	10.3	75.1	57.0
Dallas, TX	146.1	21.7	28.0	19.2
Denver, CO	30.6	10.5	19.1	62.2
Fargo—Moorhead, ND-MN	9.4	40.0	5.1	54.3
Great Falls, MT	2.0	9.2	1.9	97.0
Harrisburg, PA	9.7	12.4	8.1	83.5
Lansing, MI	4.8	6.5	.9	18.8
Lincoln, NB	13.8	26.5	6.9	49.6
Lorain—Elyria, OH	5.3	5.0	.6	11.3
Monroe, LA	32.5	81.0	26.8	82.4
Norfolk—Portsmouth, VA	59.2	19.8	15.5	26.2
Omaha—Council Bluffs, NB-IA	50.6	33.5	23.1	45.5
Phoenix, AZ	71.2	18.4	63.5	89.2
Portland, OR	14.5	5.4	8.5	58.7
Reno, NV	2.0	5.3	.9	45.0
Richmond, VA	12.9	8.9	1.7	13.2
St. Louis, MO-IL	136.1	29.6	91.7	67.4
Salt Lake City, UT	12.9	7.0	10.1	78.3
San Jose, CA	80.0	28.8	67.9	84.7
Spokane, WA	1.9	2.4	.9	47.4
Tallahassee, FL	3.1	10.4	2.6	83.9
Texarkana, TX-AR	4.7	13.8	2.1	44.2
Total	941.4		497.2	
Weighted average		16.2		52.8

Table 7-1. Areas of Selected Urban Flood Plains [Schneider and Goddard, 1974]

For 23 years after White wrote, there was no national legislation to carry out a policy of occupance restraint. During this period the only direct federal involvement other than in constructing flood control devices was to provide public relief. In a report to Congress [U.S. Congress, 1966], HUD suggests that these policies were subject to three criticisms: First, the various programs did not deal adequately with all needs or fairly with all groups within the disaster area. Even a loan at an interest rate substantially below the commercial rate still means an increased burden on the flood victim. Victims remained liable for all debts incurred before the disaster, and elderly people who were able to get along before the disaster were sometimes financially unable to carry any rehabilitation loan. Likewise, many marginal small businesses may have been put out of business, despite loan availability.

Second, much flood damage occurs under conditions that do not warrant a "disaster" designation. For example, a relatively few homes may be destroyed; from a national viewpoint, the loss is not a disaster, though it may be to the individuals concerned.

Third, public assistance was found to be repugnant to many people who highly valued their independence and self-reliance.

Thus, the Flood Insurance Act was adopted,in part, to deal with this situation. Section 1305 states that "flood insurance will be made available in only those states or areas which have evidenced a positive interest in securing flood insurance coverage under the program". Section 1315 states: "After June 30, 1970, no new flood insurance coverage shall be provided under this title in any area... unless an appropriate public body shall have adopted permanent land use and control measures ... consistent with the comprehensive criteria for land management and use under section 1361." Section 1361 establishes criteria for land management and use, supporting development of local measures for land use, flood control, flood zoning, and flood damage protection. Procedures include:

1) Adopting measures to constrict the development of land which is exposed to flood damage,

2) Guiding the development of proposed construction away from locations which are threatened by flood hazards,

3) Assisting in reducing damage caused by floods,

4) Otherwise improving the long-range management and use of flood-prone areas.

This act also authorizes studies to determine "the extent to which insurance protection against earthquakes or other natural disaster perils, other than flood, is not available from public or private sources, and the feasibility of such insurance protection being made available"; actual involvement in such studies has been limited, however.

The insurance program is managed by a pool of insurance companies, the National Flood Insurers Association (NFIA), which jointly sell and service flood insurance, and share profits and liabilities. The Federal Government makes premium equalization payments to the insurers' pool to make up the difference between below-cost premiums received and the actuarial cost of the insurance. The federal government supports private firms by guaranteeing to pay claims in excess of the financial capacity of the privately-financed pool. A National Flood Insurance Fund was created with borrowing authority for the Secretary of HUD of up to $250 million and a ceiling on outstanding insurance was placed at $2.5 billion. The Act also made flood insurance available for the first time to owners of flood-prone one-to-four family dwellings and to small businesses.

Federally subsidized rates totaled about ten percent of actuarial rates, and were available only for existing structures in the flood plain; new structures could only be insured at the actuarial rates, which in fact are prohibitive. Thus, flood plains would eventually be cleared of structures subject to flood damage. In order for a property owner to purchase federally-subsidized flood insurance, the entire community was required to become eligible for inclusion in the program by adopting flood plain management measures adequate to meet HUD standards.

However, two weaknesses in the 1968 act soon became apparent. First, the program was voluntary. Although it may have been in the long-term interest of the federal taxpayer to be partially relieved of the disaster relief burden, many communities were apparently little interested in placing a short-term hardship on their residents living in exposed areas. And second, detailed studies of individual communities were required before rates could be determined.

The Secretary was to identify flood zones, and within five years after enanctment, establish a set of actuarial flood insurance premiums based on the flood-zone statistics. As a result, of a total of 16,000 flood-prone commmunities, only four became eligible under the program during its first year. [Platt, 1976]

In 1969 Congress set up an emergency program which is still in effect. It allows communities to take part in the program with reduced amounts of coverage while the lengthy rate-making study is under way. Under the regular program, coverage is double what it is under the emergency program, and premiums are based on actuarial insurance rates. More stringent flood plain management procedures are also required. By May 1973, however, there were only 2,200 eligible communities in the program [U.S. Congress, 1975]. In order for the intent of the program to be carried out, the federal government believed that all flood-prone communities would have to participate and this participation was made mandatory by the Flood Disaster Protection Act of 1973 [P.L. 93-234].

<u>Flood Disaster Protection Act, 1973 [P.L. 93-234]</u> enacted December 31, 1973 administered by the Flood Insurance Administration (HUD) in cooperation with the National Flood Insurers Association, a pool of 132 major property and casualty insurance companies.

Under the provisions of the 1973 Act, no federally-related financial assistance shall be made for acquisition or development of any identified flood-prone property unless: a) the community in which it is located has entered the National Flood Insurance Program, and b) the applicant for such financing has purchased a flood insurance policy. Federally-related financing includes direct federal assistance of any kind and also loans by private banks and thrift institutions insured or regulated by federal instrumentalities such as the Federal Deposit Insurance Corporation [Platt, 1976].

Title I is an expansion of the National Flood Insurance Program, covering losses due to erosion and undermining of shorelines. The bill more-than-doubled flood damage coverage for homeowners and businesses. Single family dwellings can be insured for up to $35,000, and their contents for up to $10,000. Other residential buildings can be insured for up to $100,000, and their contents up to $10,000. Subsidized low-cost flood insurance is made available at 25 cents per $100 of coverage in most areas, with the federal government paying from 70-90% of the cost.

Title II deals with disaster mitigation requirements. The Secretary of the Department of Housing and Urban Development is required to identify flood-prone communities and notify them of this designation. Upon notification the community must apply for participation in the flood insurance program or prove that it is not flood-prone. The identification of flood-prone areas and criteria for land use management are required to be established by the Secretary of HUD in consultation with elected local officials. A community is designated as flood-prone if it has a 1% chance of being vulnerable to a serious flood in any year. Once it is so designated, it has one year to enter the flood insurance program before penalties are imposed.

The bill retained a provision of the 1968 National Flood Insurance Act requiring communities, as a condition of their participation in the insurance program, to adopt land use and control measures to restrain construction projects in areas exposed to possible flood damage.

In signing the bill, President Nixon said he expected it would help reduce losses from floods, which account for more than 90% of the nation's natural disaster property damage, and provide faster and fairer assistance to victims than was achieved under previous disaster relief loan programs.

However, the mandatory penalties for noncompliance have stirred a great deal of controversy and opposition. Subsequent amendments have modified certain elements of this bill. Exemptions from the ban on mortgage lending were allowed in PL 94-375 passed in July 20, 1976 when loans were:

1) used to purchase a residential dwelling occupied before March 1, 1976,

2) available for up to $5,000 to improve existing residences,

3) used to finance the purchase of a building occupied by a small business before January 1, 1976, and

4) used to finance improvements for agricultural purposes on a farm.

The bill was amended again in May 1977 to remove the prohibition of federally-insured lending institutions from making loans to property owners in HUD designated flood-prone areas which were not participants in the flood insurance program. The amendment required for lending institutions to notify the recipient that he or she would not be eligible for federal disaster relief and that the federal government could not assist individuals who undertook development in flood-prone areas without adequate flood-proofing measures. Despite the controversy surrounding this bill, more than 85% of designated flood-prone communities are participants in the program.

The federal government has encouraged participation because the insurance and preventive land-use control measures are cheaper than general disaster relief made available after the fact. The Federal Water Resources Council has estimated that the government could save about $1 billion annually if all flood-prone communities engaged in flood plain management and if all of their residents were insured. The effectiveness of the flood insurance program as presently instituted is illustrated in Table 7-2, which compares the insurance indemnifications for Hurricane Agnes, which occurred before flood insurance was made mandatory, and Hurricane Eloise, which occurred after the passage of the Flood Disaster Protection Act of 1973. Although the total flood damage to all structures and contents was 2 ½ times greater in Hurricane Agnes, the insurance indemnification for flood damage was over eleven times greater for Hurricane Eloise.

The federal government believes that the flood insurance program can realize substantial savings both to the private sector and to the federal government through reducing the costs of disaster relief well below existing levels. The mechanisms for reducing these costs are primarily land use and building code regulations.

[Comparison of the actual insurance indemnification for flood damage under the national flood insurance program in which the insurance purchase requirement was optional with the insurance indemnification under the national flood insurance program as amended by the limited insurance purchase requirement contained in the Flood Disaster Protection Act of 1973]

State	Flood damage[1]		Number of flood insurance policies in force		Amount of insurance protection in force		Number of flood insurance claims filed		Insurance indemnification for flood damage	
	Agnes	Eloise	Agnes	Eloise	Agnes	Eloise	Agnes	Eloise	Agnes	Eloise
Pennsylvania	$410,060,000	$112,800,000	683	40,180	$8,654,000	$869,576,000	146	8,000	$772,250	$37,500,000
Virginia	69,650,000	6,000,000	667	9,224	13,606,000	302,217,000	209	450	1,601,354	4,250,000
New York	41,385,000	27,420,000	2,046	25,121	43,657,000	704,264,000	7	1,650	35,000	2,438,000
Maryland	15,000,000	8,000,000	693	5,610	14,395,000	176,780,000	99	600	733,933	2,950,000
Florida	11,207,000	20,000,000	21,208	128,051	356,755,000	3,871,549,000	1,019	500	1,778,659	2,000,000
New Jersey	8,112,000	1,500,000	9,259	41,069	193,065,000	1,206,133,000	107	375	90,511	562,000
Connecticut	3,000,000	2,000,000	115	4,875	1,997,000	135,383,000	8	150	40,000	1,200,000
District of Columbia	1,000,000	400,000	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
All States	569,741,000	228,780,000	61,228	258,744	1,064,140,000	7,433,230,000	1,614	12,375	5,146,717	58,000,000

Source: National Flood Insurers Association Insurance experience and the American Insurance Association property claim services.

[1] Flood damage to structures and contents.
[2] District of Columbia entered Flood Program on Oct. 31, 1975, no insurance in force during Agnes and Eloise.

Reprinted in U.S. Congress, Oversight on Federal Flood Insurance Programs, 1975, p. 270

Table 7-2. Agnes (1972) Versus Eloise (1975)

According to J. Robert Hunter, Acting Director of the Flood Insurance Administration, without meaningful flood management $3.2 billion of flood-related losses to structures would occur by the year 2000. With the present flood insurance program, including its provisions for flood plain management by local communities, this cost can be held to $1.3 billion [U.S. Congress, 1975]. It should be noted that these estimates are less than those projected by this study [Chapters IV and V].

Table 7-3 compares the Federal Insurance Administration's estimates of economic loss with and without the flood insurance program. Estimated savings by the year 2000 under the program total $1,873 million. The reason for these widening differences, according to Hunter, relates to the distribution of new structures within the flood plains. Without flood plain management, the ratio of claims per 100 flood policies is estimated to be about 2.3, with severity of structural damage increasing at an assumed 5% inflation factor per annum. Under the flood insurance program, claim frequency is calculated to fall from 2.3% in 1975 to 1.9% in 1980, 1.5% in 1990 and 1.2% in the year 2000.

FISCAL YEAR	TOTAL ECONOMIC LOSS (MILLIONS OF DOLLARS)		
	WITHOUT FLOOD INSURANCE PROGRAM	WITH FLOOD INSURANCE PROGRAM	DIFFERENCE IN EXPENDITURES
1975	471	471	0
1980	726	571	155
1990	1,572	903	669
2000	3,209	1,336	1,873

Source: U.S. Congress; Senate Committee on Banking, Housing, and Urban Affairs, Oversight on Federal Flood Insurance Programs, November 12 and 13, 1975, p. 185

Table 7-3. Projected Economic Loss from Floods in the United States, with and without Federal Flood Insurance Program

Additionally, there should be some improvement in the severity factor because, as structures are eliminated from the housing inventory due to severe or irreparable flood damage, they will be replaced by structures built under safer flood management guidelines.

The FIA's calculations further assume a 40-year life expectancy for the average structure built in the flood plain. Under such an assumption, by the year 2015 there would be no further need for a flood insurance general tax revenue contribution or subsidy, except the possibility for some form of reinsurance for short-term catastrophic conditions [U.S. Congress, 1975].

In addition to its mitigating effects on total economic loss, the Flood Insurance Program is projected to alter the distribution of economic loss. As shown in Table 7-4, the program is projected to save significant amounts of both tax revenue and funds for the disaster victims themselves. By the year 2015, the flood insurance program is scheduled to become self-sufficient, requiring no further funds from federal taxes.

A. NO FLOOD INSURANCE PROGRAM

Year	From Insurance Funds Premiums Less Expenses	From Tax Revenues	From Disaster Victims ("Self Insurance")
1975	0	$ 188	$ 283
1980	0	290	436
1990	0	629	943
2000	0	1,284	1,925

B. WITH FLOOD INSURANCE PROGRAM

Year	From Insurance Funds Premiums Less Expenses	From Tax Revenues	From Disaster Victims ("Self Insurance")
1975	$ 269	$ 173	$ 29
1980	384	158	29
1990	678	194	31
2000	1,129	176	31

Source: U.S. Congress, Oversight on Federal Flood Insurance Programs, 1975, p. 186

Table 7-4. Distribution of Economic Losses (In Millions)

Although the National Flood Insurance Program directly affects land use, the Federal Insurance Administration points out that it is not intended to be a federal land use program. In testimony before the Senate Committee on Banking. Housing and Urban Affairs, Acting Director Hunter emphasized that land use controls are state powers delegated to local communities. The National Flood Insurance Program only requires the local adoption of flood plain management regulations, addressing new construction within flood-prone areas only for the purpose of reducing future flood losses. The flood plain management standards are performance standards, according to Hunter, focusing on the ends of reducing or eliminating future flood damage to new construction--ends that the Congress cited as a primary objective of both the 1968 and 1973 acts. [U.S. Congress, 1975].

In summary, the National Flood Insurance Program is intended to reduce economic loss and the loss due to floods, and was implemented as a result of rising costs to the federal government in providing relief to flood victims. Although it was not intended directly as a federally-monitored land use program, in effect the mandatory nature of the program after 1973 has put the federal government in the position of establishing performance standards for land uses and building construction requirements in flood plains. The 1977 amendments, however, reduce some of the action-forcing authority of the federal government.

Two consequences, one hypothetical and one actual, of the flood insurance program are important for the public recommendations of this study with respect to natural hazards other than flood. First, the existing flood insurance program is intended to transfer flood-induced economic loss from federal disaster relief funds to municipalities and private property owners. However, for about the next half century, the federal government will be absorbing much of the cost of flood losses through insurance subsidy rather than through disaster relief payments. To the extent that property owners will take no additional action for flood protection once they have purchased insurance, their vulnerability and higher value at risk may increase, thereby creating greater federal expenses rather than lessening them until such time as a structure is destroyed by flood and cannot be rebuilt.

A second important consequence of the National Flood Insurance Program is the organization of groups opposed to required flood insurance. The Flood Insurance Litigation Coalition has been formed to challenge the constitutionality of the Flood Disaster Protection Act of 1973. The coalition was largely coordinated by the Texas Landowners Rights Association and residents of the City of Cape Girardeau, Missouri. By March 1977, seven month after the coalitions' founding, a total of $164,000 in contributions had been received, and litigation challenging the act was under preparation when the 1977 amendments were adopted to remove the mandatory insurance requirements for individual property owners.

Whatever the resolution of the flood insurance issue, it will stand as an important model from which to judge potential mitigation policies with respect to other hazards. The question of the degree to which government may reasonably intervene in traditional private sector decisions, with the purpose of protecting the citizenry from economic loss and bodily harm, must be addressed in any natural hazard policy consideration.

National Dam Inspection Program [PL 92-367] enacted August 8, 1972 and administered by the Secretary of the Army

This bill authorizes the Secretary of the Army to carry out a national dam inspection program of more than 28,000 non-federal dams in the United States. It does not apply to dams under the jurisdiction of the Bureau of Reclamation, the Tennessee Valley Authority, the International Boundary and Water Commission, or the Federal Power Commission; dams which were inspected in the past 12 months; or dams which pose no threat to human life or property. The Secretary was directed to issue a report to Congress by July 1, 1974 which would include an inventory of all dams, a review of inspections and recommendations and a suggested national program for dam safety regulation.

A report by the House Public Works Committee [H Rep 92-1232] supporting the passage of the act noted that state programs for licensing and inspection of non-federal dams varied greatly in scope and effectiveness. It cited the dam failures at Buffalo Creek, West Virginia, and Rapid City, South Dakota, as examples of disasters which might be prevented by passage of the bill.

The report said the bill would "provide an accurate assessment of the scope of the problems and an appropriate sharing of responsibility between federal, state and local governments and public and private interests." The estimated cost of the program was $90 million.

However, the implementation of this bill was delayed after its passage, due to the assignment of a relatively low priority by the executive branch.

A major disaster due to dam failure occurred with the collapse of the Teton Dam in Idaho on June 5, 1976. Eleven people died, 1,000,000 acres were destroyed, 16,000 head of livestock killed, and $1 billion lost in property damage. Payment of claims arising from the disaster cost the U.S. $549 million. This was a Bureau of Reclamation project and thereby exempt from the dam inspection legislation. It was, however, the first dam failure in the Bureau's 75-year history. The investigation panel of the House Government Operations Committee issued a report [H Rep 94-1667] on Sept. 23, 1976, with the findings:

1) There exists within the Bureau of Reclamation a "bureaucratic momentum" to build dams, once construction is begun the decision to halt construction is no longer an option. Safety problems are generally met with unquestioned reliance on the Bureau's abilities to "engineer" workable solutions.

2) The Bureau was deficient in its examination of the geologic site of the Teton Dam.

3) The Bureau was deficient in responding to warnings that the site might be dangerous.

4) The United States Geological Survey was deficient in withholding information about geologic hazards at the Teton Dam site from the Bureau for six months.

Although this report and the disaster did not result in any legislative action, President Carter reactivated the 1972 Dam Inspection Program on November 28, 1977, [Los Angeles Times, 1977]. Earlier that year, Congress took the initiative and voted $15 million for federal inspection of private dams, but it was the November 5, collapse of a never-inspected dam near Toccoa, Georgia that led President Carter to implement this program. Inspections were to be carried out by the Corps of Engineers; 2,000 dams can be checked with the $15 million congressional appropriation. The president indicated he was committed to a multi-year program so that all high-hazard dams could be inspected within the next four years. His administration seeks to encourage states to share responsibility for inspection. California's Dam Safety Program was cited as exemplary, spending about $2 million annually inspecting and regulating more than 1,000 private, municipal and state-owned dams.

In addition these statutory flood-related measures, two executive orders particularly address the flood hazard. Executive Order 11988, issued May 24, 1977, mandates that each federal agency "provides leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains" as a part of the regular activities of that agency. The executive order sets forth specific procedures for federal agencies in carrying out these measures. Executive Order 11990, of the same date, requires similar consideration for wetlands.

Coastal Hazard Mitigation

Mitigation of the effects of coastal natural hazards is one of several objectives of the Coastal Zone Management Act of 1972 [P.L. 92-583]. Among the elements required to be addressed in a proposed coastal plan is the issue of "floods and flood damage prevention, erosion (including the effect of tides and currents upon beaches and other shoreline areas), land stability, climatology and meteorology" [Federal Register, January 9, 1975, p. 1685, section 923.4]. To meet this and other coastal planning objectives, Congress requires each coastal state to submit a proposed management program in order to qualify for administrative grant assistance under Section 306 of the Coastal Zone Management Act. Proposed programs should employ the following general techniques for control of land and water uses within the coastal zone:

1) State establishment of criteria and standards for local implementation, subject to administrative review and enforcement of compliance,
2) Direct state land and water use planning and regulation, and/or
3) State administrative review for consistency with the management program of all development plans, projects, or land and water use regulations,...

In the Coastal Zone Management Act Amendments of 1976 [PL 94-370 Section 4] Congress required state "306 plans" to provide a planning process for assessing the effects of shoreline erosion, and studying ways to lessen the impact of erosion, and to restore eroded areas. [NOAA, 1976]

Nine natural hazards are of particular concern to NOAA under the Coastal Zone Management (CZM) Act. In a 1976 report, Natural Hazard Management in Coastal Areas, NOAA notes the status of public policy with respect to these hazards, and the consequent role to be played by CZM:

Hurricane: More than 6 million* people are currently exposed to hurricane storm surge in areas where the population is growing at a rate 3-to-4 times as fast as the national average. Although warning systems are improving, expanding occupancy of vulnerable areas and the lack of hurricane experience by young persons and relative newcomers results in an enlarging naive population and volume of property subject to damage. Hurricane winds and tornadoes may extend the impacts to much larger populations.

Flood: Valleys subject to fresh water flooding frequently enter the coastal zone and in some places have been protected by engineering works. The requirements of the Flood Insurance Act for local land use planning in vulnerable areas have spurred the delineation of flood hazard lands and the enactment of local land use regulations to curb the increasing trend toward expansion of property in lands subject to floods with annual recurrence probabilities of one per cent.

Coastal Erosion: Coastal erosion is significant along a quarter of the national shore front, and in as many as 2,700 miles it is a critical problem. In addition to protective works, dune stabilization, and beach nourishment, a wide range of land use controls is available to cope with continued erosion. Currently there is a shift in emphasis toward land use management as an alternative strategy to erosion control.

Landslide: Although landslides can occur widely, there is no explicit national policy for dealing with this hazard. Only recently and in a few states has there been extensive effort to combine land management with abatement of landslide.

Earthquake: Accurate and consistent earthquake prediction has not yet been demonstrated. Other measures which promise major reduction in vulnerability to earthquake damage include the requirement of earthquake-resistant construction, land use management, and preparedness planning. For most of the vulnerable areas of the country, and particularly those away from the Pacific Coast, little progress has been made in incorporating these measures into earthquake loss reduction planning.

*For the baseline year of 1970 9.9 million people and 104 trillion dollars of building value were estimated to be exposed to storm surge flooding in this study [See Table 7-4]

Tsunami: Except for an improved warning system and for pioneering efforts in Hawaii, there has been relatively little action in reducing vulnerability to tsunami waves. The amount of property and number of lives susceptible to this rare but catastrophic hazard is mounting.

Volcano: The lava flows in Hawaii are relatively well defined and subject to prediction. Pyroclastic flows and ash flows resulting from violent eruptions are more or less predictable, are less frequent, and constitute a large but rare threat along the Pacific Coast and Alaska.

Avalanche: In a few parts of Alaska snow avalanche is a significant hazard, and only recently has there been serious consideration of a variety of measures, including land management, to deal with them.

Land Subsidence: In parts of both the California and Gulf coasts there is threat of increasing vulnerability to natural hazards from land subsidence resulting from pumping of water, oil, and gas.

In developing state policies for the mitigation of these natural hazards, NOAA [1976] recommends the following general types of action by the individual states:

1) Hazard areas along each section of the coast should be designated.

2) Coastal management offices should assure that all parties concerned are aware of the range of adjustments to a hazard and of the costs and benefits related to each adjustment.

3) Efforts should be made to find out which channels of information about hazards have higher credibility in the view of the people for whom the information is designed, and those channels should be used for disseminating information about the hazard.

4) Descriptions of the proposed change in adjustments to hazards also should discuss the existence or creation of the necessary powers to promote the new work within state or local agencies. Specific consideration should be given to ways in which planning for natural hazards in coastal areas can be linked with emergency planning for disasters under Section 201 of the Disaster Preparedness Act of 1974.

The Coastal Zone Management Act is intended to provide an opportunity for state coastal zone management agencies to find effective ways of applying to coastal areas the concepts, information, and analytical methods previously developed in natural hazard studies. To do so, according to NOAA, can reduce the vulnerability of the nation to catastrophe and enhance the resilience of land and water uses along the coast.

Disaster Relief Legislation

Disaster Relief Act, 1974 [P.L. 93-288], enacted May 22, 1974
administered by the Federal Disaster Assistance Administration (FDAA).

This legislation intends to alleviate the suffering and damage which result from disasters. It provides federal assistance for both public and private losses sustained in disasters and provides a long-range recovery program for major disaster areas.

The Act applies to major catastrophes, defined as: hurricane, tornado, storm, flood, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, drought, fire, explosion, or other catastophe which is so determined by the president. The program is initiated upon declaration by the president that a major disaster or emergency exists. Although primarily concerned with providing post-disaster relief, this bill contains some disaster mitigation measures.

First, states and local governments are encouraged to apply for and may receive up to $250,000 for the development of a comprehensive program for disaster preparedness and prevention, including mitigation, warning, emergency operations, rehabilitation, recovery, application of science and technology, and research. It also provides for development of an effective disaster warning program, utilizing Civil Defense or other communications systems. This element aims at improving disaster relief by supporting better coordination and responsiveness among existing disaster relief programs. The preparation of disaster preparedness plans was first written into the Disaster Relief Act of 1969; as of September 1976, all but one state was utilizing federal funds for these studies.

Second, states, local governments, and individuals are encouraged to protect themselves by obtaining insurance coverage to supplement or replace government assistance. Owners of property which has been repaired or restored with federal disaster relief funds are required to obtain disaster insurance as a condition for receiving future federal disaster assistance. This requirement does not apply to individual homeowners, but only to state and local governments, non-profit institutions and public works projects.

The question of insurance was raised in a Senate committee report on the implementation of the 1969 Disaster Relief Act following Hurricane Camille. A special subcommittee on Disaster Relief, under the Senate Public Works Committee and chaired by Birch Bayh (D., Indiana) recommended some form of all-risk insurance. Testimony taken by the committee indicated that existing insurance coverage was inadequate protection in disasters like Camille, and it was suggested that such programs might have to be supervised and financed by the federal government. Property insurance coverage for extreme natural events was also recommended in President Nixon's message to Congress on April 22, 1970, on disaster relief and Hurricane Camille.

Third, the law encourages hazard mitigation measures to reduce losses from disasters, including development of land use and construction regulations. It requires the reconstruction or replacement of federal facilities to be evaluated with regard to natural hazard exposure. In particular, any loans or grants made under the provisions of this act shall be made with regard to mitigating natural hazards through safe land use and construction practices.

Under this provision, the FDAA provides technical assistance regarding codes, standards, and specifications for the repair or reconstruction of public and private structures.

Other major provisions of the Act are: appointment of a federal coordinating officer to operate in the affected area, mobilization of federal personnel as emergency support teams, assistance of federal agencies in distributing food, supplies and medicine, removal of debris, etc., use of local firms for assistance and recovery work, provision for nondiscrimination in disaster assistance, priority for public housing assistance, repair and restoration of damaged public facilities, temporary housing assistance, unemployment assistance and increased benefits, relocation assistance, family and individual counseling for mental stress, and loans and grants to local governments for economic recovery.

Amendments and supplemental appropriations are occasionally added to deal with special situations. Disaster relief amendments [PL 92-209] provide federal financial assistance for private nonprofit medical care facilities damaged or destroyed by major disaster after January 1, 1971. This amendment made available to these facilities the same type of grants offered to publicly owned facilities and resulted from the damage to seventeen hospitals in the Los Angeles area after an earthquake in February, 1971.

Another extension of benefits to the private sector was a 1972 bill to permit tax deductions for disaster losses [PL 92-418]. Persons who suffer property losses in the first six months of a taxable year due to an event in a presidentially-declared disaster area could file an amended federal income tax return for the previous year, claiming uninsured losses as a deduction. Payments for the period 1953 to 1973 under this and preceding acts are shown in Table 7-5.

AGENCY	AMOUNT
1. Federal Disaster Assistance Administration (FDAA), formerly Office of Emergency Planning and Office of Emergency Preparedness (OEP)	$1,844,827,290
2. Small Business Administration	809,254,922
3. Farmers Home Administration	448,180,766
4. Department of Agriculture	18,415,159
5. Federal Highway Administration, formerly Bureau of Public Roads	484,637,000
6. U. S. Army Corps of Engineers	299,341,940
7. Veterans' Administration	2,000,000
8. Office of Education	102,330,691
9. Federal Insurance Administration	46,774,000
Total	$4,051,761,768

Table 7-5. Direct Federal Expenditures for Disaster Assistance, 1953-1973. [Cochrane, 1975]

Earthquake Legislation

Earthquake Hazards Reduction Act [PL 95-124] enacted October 1977;
federal agency responsible to be designated by the President

This bill recognizes earthquake as a major natural hazard, and deals with prevention and mitigation methods in a comprehensive way. It authorizes appropriation of $250 million over three years to develop means of reducing the impact of earthquakes by improving methods of prediction, and by developing building and land use standards for earthquake-prone regions.

Both the Senate and House versions of the bill authorized $102.5 million for earthquake research budgets of the United States Geologic Survey (USGS) and the National Science Foundation (NSF). The House bill also provided $5 million for other participating agencies, while the Senate put no ceiling on these authorizations. The House bill also included language designed to increase participation through an advisory committee. The committee's initial recommendation are presented in the report by the Working Group on Earthquake Hazards Reduction, [Steinbrugge, 1978].

The major elements provided by the bill are:

1) An implementation plan to carry out a national earthquake hazards reduction program. The plan, to be prepared by the executive branch, is to ensure informed coordination of land use, building design, public information, insurance, warning and relief activities by federal, state and local agencies. Eight federal agencies are to be involved in the plan in addition to the USGS and the NSF. The target date for a functioning program is 1985.

2) Research by USGS and NSF into earthquake prediction, causes and mechanisms of earthquakes, zoning guidelines, preparation of seismic risk analysis for emergency planning, developing earthquake mitigation techniques in man-made structures and in social and economic adjustments.

The main objectives of the bill are:

1) Development of earthquake resistant construction and design methods for public and high occupancy buildings in areas of seismic risk.

2) Development of procedures for identifying seismic hazards and predicting damaging earthquakes.

3) Coordination of information about seismic risk with land use policy decisions and building activity.

4) Development of improved methods for controlling the risks from earthquakes and planning to mitigate such risks; also planning for reconstruction and redevelopment after an earthquake.

5) Public education regarding earthquake and ways to reduce the adverse consequences should an earthquake occur.

6) Development of research on utilization of scientific and engineering knowledge to mitigate earthquake hazards. The social and economic, legal and political consequences of earthquake prediction, and ways to assure the availability of earthquake insurance or some functional substitute.

7) Development of research applied to control or alteration of seismic phenomena.

The role of zoning and building practices is of greatest interest in the context of this study. In a report to the U.S. House of Representatives by the Committee on Science and Technology (May 11, 1977), proposing adoption of the bill, zoning practices are discussed as follows:

> Of all the potential mechanisms to avoid earthquake hazards, the simplest and most direct would be zoning. Although cities cannot be relocated and undeveloped high-risk areas may be potentially very valuable, several courses of zoning action may by feasible:
>
> 1. Risk zoning of critical parts of already-developed areas to turn them into park land or other nonhazardous use as opportunity arises.

2. Risk zoning of high risk undeveloped areas to prevent future hazardous development.

3. Development of systematic techniques for collection and evaluation of data for use in microzoning (zoning of comparatively small areas) and the establishment of criteria for microzone levels of risk.

4. Adoption of building codes which require higher levels of earthquake resistance in higher risk areas.

Since many areas of high seismic risk are already heavily developed and populated,the promotion of earthquake resistant building practices is receiving priority consideration as an effective approach to minimize earthquake damages from ground movement, which causes over 90 percent of the damages. Even if an earthquake is anticipated and residents have evacuated the area, there is still a need to reduce the damage to buildings and other facilities. If there has been no advance warning and no evacuation, the need for safer building is obviously critical.

Since the greatest earthquake hazards result from inadequacies in building construction, this is obviously an area in need of close attention. The current state of the art in defining seismic design criteria and in earthquake resistant construction techniques leaves much to be desired. Therefore, additional research to advance the state of the art is of critical importance. Buildings not constructed in accord with adequate design provisions should be evaluated and, if found to be hazardous, should be strengthened or replaced. So that new construction should not add to the earthquake hazards , seismic design criteria providing appropriate resistance should be incorporated in building regulations and enforced.

The costs of adopting building standards designed to reduce earthquake hazards vary considerably. Witnesses estimated that the implementation of seismic standards increase new building costs one-to-six percent.

The costs can run much higher for special buildings such as hospitals. The earlier earthquake resistance is introduced into the construction process, the less the cost increase.

Advocates of the legislation contended it was needed because more and more Americans live in high-risk areas on both coasts, because scientific advances make accurate prediction a real possibility, and because seismological data is needed to evaluate site selection for nuclear power plants. A prime example cited is the Diablo Canyon, California, nuclear power plant. In 1971, after work was well under way on the billion-dollar plant, a potential active fault was discovered under nearby coastal waters. An expert testified that the fault could produce an earthquake about double the intensity that the plant was originally designed to withstand; the utility company is now reanalyzing its design.

Although the debate over the proper approach to earthquake mitigation continues, the act offers the opportunity to search for far-reaching answers to the earthquake threat in the United States.

Other Hazard-Related Programs

In addition to the major interests examined above, the federal government administered numerous other hazard-related programs. Figure 7-3 is a summary of current federal programs relating to each of the nine natural hazards studied in the current project. Included are predisaster functions (emergency preparedness to mitigate the effects of the disaster), post-disaster functions (emergency preparedness for disaster relief), and natural disaster warning activities.

For example, the Farmers Home Administration (Department of Agriculture) administers Watershed Protection and Flood Prevention Loans; program number 10.419 in the Catalog of Federal Domestic Assistance. The "Uses and Restrictions" of such loans, as described in the catalog, read in part:

> Loan funds may be used to help local sponsors provide the local share of the cost of watershed works of improvement for *flood prevention,* irrigation, drainage, water quality management, sedimentation control, fish and wildlife development, public water based recreation and water storage and related uses. (Italics added)

This program is indicated in Figure 7-3 as having a pre-disaster function (disaster mitigation) for riverine floods. Although there seems to be no prohibition in the program description against funds being used for storm surge mitigation, this use would seem to be highly unlikely and therefore it is not so indicated. FmHA also administers emergency loans "to assist farmers, ranchers and aquaculture operators with loans to cover losses resulting from a national disaster," which includes natural disasters. These loans are a post-disaster function, to provide disaster relief for victims.

Other agencies with programs in flood hazard mitigation include the Bureau of Reclamation and the Soil Conservation Service, as well as some regional agencies such as the Tennessee Valley Authority. Most other federal programs appear to be directed toward disaster relief with the exception of the National Science Foun-

FEDERAL AGENCY OR ACTIVITY	PROGRAM	PROGRAM NUMBER	EARTHQUAKES	HURRICANE WINDS	TORNADOES	TSUNAMIS	LANDSLIDES	RIVERINE FLOODS	STORM SURGE	SEVERE WINDS	EXPANSIVE SOIL
Farmers Home Administration (DOA)	Emergency Loans	10.404	□		□	□	□		□		
	Watershed Protection and Flood Prevention Loans	10.419						■			
Agricultural Stabilization and Conservation Service (DOA)	Emergency Conservation Measures	10.054	□	□						□	
Soil Conservation Service (DOA)	Resource Conservation and Development	10.901						■			
	Water Shed Protection and Flood Prevention	10.904						■			
Agriculture Research Service (DOA)								R			
Economic Research Service (DOA)								R			
U.S. Forest Service (DOA)								■			
Economic Development Administration (DOC)								R			
Bureau of Economic Affairs (DOC)	Technical Services							■	■		
Department of the Army Office of the Chief of Engineers (DOD)	Flood Control Works (Rehabilitation)	12.102		□		□		□	□	□	
	Flood Fighting and Rescue Operations	12.103						□	□		
	Flood Plain Management Services	12.104						■	■		
	Emergency Bank Protection	12.105						□			
	Small Flood Control Projects	12.106						■	■		
	Snagging and Clearing	12.108						■	■		
	Planning Assistance to States	12.110						■	■		
	Dam Inspection							■			
Public Health Service (HEW)	Emergency Medical Service Planning	13.284	□	□	□	□	□	□	□	□	
Housing Protection and Mortgage Credit/FHA (HUD)	203h: Mortgage Insurance: Disaster Victims	14.119	□	□	□		□	□	□	□	
Federal Disaster Assistance Administration (HUD)	Disaster Assistance	14.701	□	□	□	□	□	□	□	□	
Federal Insurance Administration (HUD)	National Flood Insurance Program	14.001					■*	■	■		
Defense Electric Power Administration (DOI)	Electric Power Planning for Emergencies	USGM 281	□	□				□		□	
Bureau of Reclamation (DOI)	Reclamation Projects	15.504						■			
Bureau of Land Management (DOI)								■			
Bureau of Outdoor Recreation (DOI)	Grants & Loans							■	■		
Forests & Wildlife Service (DOT)								R			
U.S. Coast Guard (DOT)								□	□		
Federal Aviation Administration (DOT)								■	■		
Federal Highway Administrations (DOT)								■	■		
Federal Railway Administrations (DOT)								■	■		
National Science Foundation	Basic Research	47.000-47.052	R	R	R	R	R	R	R	R	R
Small Business Administration	Loans to Natural Disaster Victims	59.008	□	□	□	□	□	□	□	□	
Tennessee Valley Authority	Water Resources Development	62.003						■			
Federal Crop Insurance Corp. (DOA)	Crop Insurance	10.450		□				□			
U.S. Geological Survey (DOI)	Prediction		■			■	■	■			
National Weather Services (NOAA)	Hazard Warnings			■	■	■		■	■	■	
National Meterological Center (NOAA)	Hazard Warnings				■						
National Science Storm Forecast Center (NOAA)	Hazard Warnings				■						
Radar Report and Warning Coordination Circuit(NOAA)	Hazard Warnings			■	■						
GOES - Satelite System (NOAA)	Hazard Warnings			■	■	■					
National Hurricane Center (NOAA)	Hazard Warnings			■							
National Tsunami Warning Center (DOI)	Hazard Warnings					■					
Office of Coastal Zone Management (NOAA)	Coastal Hazard Mitigation: 11.418-11.424		■	■			■	■	■	■	

Legend:

*mudslides only

■ Programs with pre-disaster functions (disaster mitigation)
□ Programs with post-disaster functions (disaster relief)
R Programs with natural hazard research functions

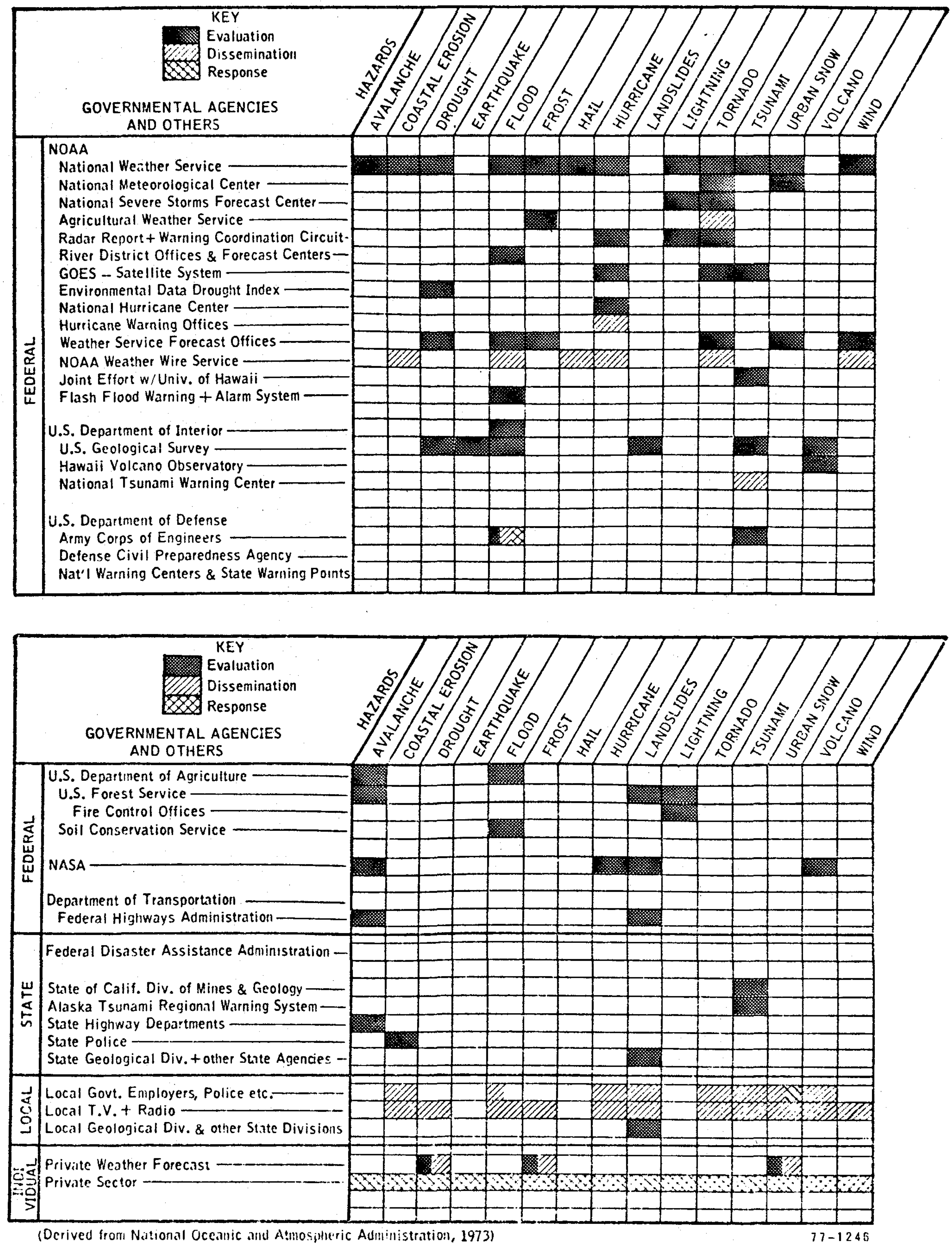
Figure 7-3. Current Federal Programs Relating to Natural Hazards dation and the U.S. Geological Survey, which sponsor basic and applied research. Disaster relief programs include loans to victims, insurance for crops and buildings, emergency physical rehabilitation programs, and planning for disaster preparation.

The federal government, particularly the National Oceanic and Athmospheric Administration, also provides warnings for five of the hazards studied here (floods, (floods, hurricanes, tornadoes, tsunami, and severe wind). Although no earthquake warning system has been developed, the U.S. Geological Survey is performing significant research in this field and currently provides date relative to earthquake and landslide prone areas. Storm surge warnings are included as hurricane warnings. No warning is provided for expansive soil, since it poses no sudden and unexpected threat. Figure 7-4 provides perspective on current warning systems and the NOAA administrative units concerned with specific hazards.

Proposed Federal Emergency Management Agency

The federal administration has recognized the widespread activities of federal agencies with respect to natural hazards, and on June 19, 1978, President Carter proposed the creation of a Federal Emergency Management Agency. If adopted, this measure would merge five agencies into one new agency: The National Fire prevention and Control Administration would be transferred to the new Federal Emergency Management Agency from the Department of Commerce, as would the Federal Insurance Administration from HUD, oversight responsibility for the Federal Emergency Broadcast System from the Executive Office of the President, the Defense Civil Preparedness Agency from the Department of Defense, the Federal Disaster Assistance Administration from HUD, and the Federal Preparedness Agency from GSA.

Several additional transfers of emergency preparedness and mitigation functions would be made to the new agency, including oversight of the Earthquake Hazards Reduction Program, now under the Office of Science and Technology Policy of the Executive Office of the President, federal dam safety activities of the same office, responsibility for assistance to communities in the development of readiness plans for severe weather-related emergencies (including floods, hurricanes, and tornadoes), coordination of natural and nuclear disaster warning systems,



Source: (Mileti, 1975, pp. 28-29)

Figure 7-4. Current Government Programs for Natural Hazard Warnings and coordination of preparedness planning to reduce the consequences of major terrorist incidents.

According to the president's proposal, this reorganization is based on the principles that, first, federal authorities responsible for actions related to major civil emergencies should be supervised by one official responsible to the president. Second, an effective civil defense system requires the most efficient use of all available emergency resources while, third, emergency responsibilities should, whenever possible, remain within the regular missions of federal agencies. And finally, federal hazard mitigation activities should be closely linked with emergency preparedness and response functions.

The proposal suggests that cost savings of from $10 to $15 million annually can be expected, without significant reductions in program expenditures for the transferred agencies and authorities.

State Land Use Regulatory Authority

Although state level policies which specifically address natural hazards are relatively limited in number, all states have adopted land use policies which may serve as a framework for natural hazard mitigation. J.A. Kusler [1976] summarizes and analyzes state statutes authorizing local governments and state agencies to adopt zoning regulations, subdivision controls, building codes, and special flood hazard regulations, with emphasis on land use control for the regulation of flood prone areas. The Seventh Annual Report of the Council on Environmental Quality [1976] summarizes state land use and planning authority in categories complementary to those devised by Kusler . The CEQ noted that by mid-1976, most states had an active interest in land use controls -- something that was rare only five years earlier when The Quiet Revolution in Land Use Control was published by CEQ, reviewing the "pioneering efforts of a few states and regions to restructure government and to fashion policies for improving land development decisions."

Figure 7-6, developed from the Kusler and CEQ reports, summarizes the current statutory authority of the fifty states with respect to land use policy, with special reference to flood mitigation authority. The following is a brief discussion of land use policies contained in Figure 7-5. Building code policies will be discussed in a later section.

State	General Authorization: Subdivision	General Authorization: Building Code	Home Rule Powers: General	Home Rule Powers: Special Reference to Land Use	Extraterritorial Controls: Subdivision	Extraterritorial Controls: Zoning	Extraterritorial Controls: Building Code	Prior Planning Requirements: Comprehensive Plan for Zoning	Prior Planning Requirements: Comprehensive Plan for Subdivision	Prior Planning Requirements: Flood or Drainage Language	Enabling Authority for Adoption of Interim Regulations: Zoning	Enabling Authority for Adoption of Interim Regulations: Subdivision	Sensitive Land Uses Included in Regulations: Subdivision: Public Utilities	Sensitive Land Uses Included in Regulations: Subdivision: Agriculture	Sensitive Land Uses Included in Regulations: Subdivision: Large Lots	Sensitive Land Uses Included in Regulations: Zoning: Agriculture	Sensitive Land Uses Included in Regulations: Zoning: Non-Conforming Uses Regulated	Sensitive Land Uses Included in Regulations: Wetlands	Sensitive Land Uses Included in Regulations: Power Plant Siting	Sensitive Land Uses Included in Regulations: Designation of Critical Areas	Comprehensive Permit System	Coordinated Incremental Planning	Mandatory Local Planning	Differential Assessment Laws	Statutes Authorizing Adoption of Flood Plain Regulations by State Agencies	Local Flood Hazard Regulations Specifically Authorized: Zoning	Local Flood Hazard Regulations Specifically Authorized: Subdivision	Local Flood Hazard Regulations Specifically Authorized: Building Code	State
AL		●	●	●	●			●	●	●				●	●	●			●						●	●	●	●	AL
AK								●					●	●	●	●	●		●			●		●			●		AK
AZ	●		●		●	●				●			●						●			●		●	●	●	●	●	AZ
AR					●	●				●			●	●	●	●			●					●	●	●	●	●	AR
CA	●	●	●		●			●		●	●		●			●	●		●			●		●	●	●	●		CA
CO	●		●		●			●	●	●	●		●	●	●	●			●	●				●	●	●	●	●	CO
CT		●	●					●	●	●			●	●	●	●		●	●			●		●	●	●	●		CT
DE			●					●					●			●		●				●		●		●	●		DE
FL	●	●	●			●		●	●				●	●		●	●	●	●	●	●	●	●	●		●	●		FL
GA	●	●	●	●	●	●		●	●	●			●	●			●	●				●				●			GA
HI	●							●					●	●	●	●			●	●	●	●		●	●	●	●	●	HI
ID			●		●			●			●	●	●				●						●	●					ID
IL			●		●	●				●									●					●	●	●	●	●	IL
IN		●			●	●			●	●			●	●	●	●	●					●		●	●	●	●	●	IN
IA	●	●	●	●	●	●		●					●	●	●		●							●	●	●			IA
KS	●		●		●	●		●	●				●	●	●										●	●	●		KS
KY					●	●		●	●	●	●	●							●					●	●	●	●		KY
LA			●	●				●		●			●		●	●	●	●								●	●	●	LA
ME	●	●	●					●	●				●	●		●	●	●	●	●	●	●	●	●	●	●			ME
MD		●	●	●	●			●	●	●			●		●		●	●	●	●		●		●	●		●		MD
MA		●	●										●	●	●	●		●	●					●	●	●	●		MA
MI	●		●	●				●	●	●	●		●	●		●								●	●	●	●		MI
MN	●	●	●		●	●		●			●		●	●	●	●		●	●	●		●		●	●	●	●		MN
MS								●					●		●		●	●							●				MS
MO			●		●	●		●	●									●	●					●	●				MO
MT	●	●			●	●	●	●		●	●		●						●	●		●	●	●	●	●	●		MT
NE			●		●	●	●	●	●				●	●		●			●				●	●	●	●			NE
NV	●	●	●					●		●			●			●	●		●	●		●	●	●		●	●		NV
NH								●			●		●	●	●	●		●	●					●			●		NH
NJ			●		●	●		●		●			●			●		●	●					●	●	●	●		NJ
NM	●				●	●	●	●		●			●	●	●	●	●		●			●		●		●	●		NM
NY	●	●	●					●		●			●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	NY
NC		●			●	●	●	●					●	●			●	●				●		●	●	●			NC
ND	●				●	●		●	●				●	●	●				●					●		●			ND
OH		●	●		●			●	●				●	●					●					●					OH
OK			●					●	●	●			●		●									●	●				OK
OR	●	●	●		●	●		●			●		●	●		●			●	●		●	●	●			●		OR
PA			●					●		●			●			●	●	●	●	●				●	●	●	●		PA
RI		●	●					●					●	●	●	●		●	●			●		●		●			RI
SC		●			●			●	●	●			●	●		●	●		●					●		●	●		SC
SD					●	●		●	●	●	●		●	●	●	●	●			●				●					SD
TN		●	●		●	●			●				●	●	●				●							●	●		TN
TX			●	●	●			●					●		●	●	●	●						●		●	●	●	TX
UT			●					●	●	●	●		●		●	●	●					●		●		●	●	●	UT
VT	●							●		●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	VT
VA		●			●					●			●	●	●	●		●					●	●		●	●		VA
WA	●	●	●		●			●			●		●	●		●	●	●	●			●		●	●	●	●		WA
WV			●	●					●	●			●	●	●										●	●			WV
WI	●	●	●		●	●		●		●	●		●	●	●	●		●	●	●		●			●	●			WI
WY					●			●	●				●	●	●	●			●			●	●	●					WY

Source: Statutory Land Use Control Enabling Authority in the Fifty States, Prepared for the Federal Insurance Administration by J.A. Kusler Associates Publication No. HUD FIA-179; September 1976, and Seventh Annual Report of the Council of on Environmental Quality Washington D.C.: GPO, September 1976

Figure 7-5. Land Use and Building Code Authority in the United States

General authorization - All states have authorized the adoption of zoning regulations, but only twenty have adopted requirements for sudivision regulations at the state level. Typically, these statutes require or allow the adoption of subdivision regulations by local government units under certain statewide guidelines. Thirteen of the states refer to the Interstate Land Sales Act (Arizona, California, Colorado, Florida, Georgia, Hawaii, Iowa, Kansas, Minnesota, New York, North Dakota, Oregon, and Washington). To the extent that natural hazard policy is to be established at the state level, many important provisions can be inserted into existing statutes within the current regulatory framework, without having to prepare and adopt a basic legislative package.

Home rule powers - Thirty-four states have allowed home rule for at least some local government units, and eight of these states make special reference to land use regulation in their home rule statutes. Some other states grant special powers to their largest cities. Home rule can be important for communities in adopting flexible and sensitive natural hazard mitigation policies for their jurisdiction.

Extraterritorial controls - In addition to the strength of local statutory authority in natural hazard mitigation activities, the geographical extent of local regulation is important in the ability of a governmental unit to establish an areawide natural hazard policy. This geographical extent is usually expressed as extraterritorial controls over subdivisions, zoning districts, and building code provisions. Extraterritorial controls are important in influencing the development of lands which are presently outside a municipal boundary, but which may be annexed as the city expands. Through these controls, a municipality may be saved the burden of annexing haphazardly-developed land. Also, natural hazard conditions surrounding a city may influence the effects of an extreme natural event within the municipality. For example, inappropriate development on outlying hillsides can pose a landslide danger which threatens transportation and communication networks vital to city residents.

Of the fifty states, 31 grant extraterritorial subdivision controls to their municipalities, generally extending three-to-five miles beyond corporate limits. Twenty-one states grant extraterritorial zoning controls to their municipalities. In a few states, there is concurrent jurisdiction between municipalities and counties, and in others the county government has primary responsibility for subdivision and zoning. Four states which authorize both extraterritorial zoning and subdivision controls also authorize extraterritorial building code authority.

Prior planning requirements - The Model State Zoning Enabling Act, published by the U.S. Department of Commerce in 1926, directs that zoning shall be "in accordance with a comprehensive plan," and municipal zoning ordinances typically have incorporated this terminology. A comprehensive plan for a municipality is important for several reasons beyond that of generally promoting "orderly development." Kusler [1976] points out that the extent of encroachment allowed in a flood plain depends partly on the availability of land elsewhere for similar purposes. If land elsewhere is available for, say, industrial uses, such should be excluded from flood plains even if the buildings could be floodproofed. Second, land uses in areas surrounding a critical area for natural hazards may help to define the boundaries of high risk areas. Again, it is a matter of relating the level of restrictions to the potential for loss resulting from a given occurrence of a natural event.

In addition, a comprehensive plan may specify density of development and, to a certain extent, building types, to support development which will be less susceptible to damage during a given type of natural disaster. And the circulation element of the plan can help assure that the street network will not easily be disrupted in an emergency.

Kusler notes that zoning in 32 states must be in accordance with a comprehensive plan, and ten states require even more explicit planning prior to the adoption of zoning regulations. Twenty-two states require a comprehensive plan, master plan, or at least a street or transportation plan prior to the adoption of subdivision regulations. And 27 states include specific flood or drainage language in the comprehensive plan enabling authority. In practice, however, a comprehensive planning requirement is nearly universal in the Unites States, since it has been an integral part of the HUD 701 planning process.

Interim regulations - Another important tool for effective natural hazard mitigation policy as discussed by Kusler is the authority to adopt interim regulations. Ordinances which suspend all development for a specified period of time are the most common regulations of this type. Such ordinances, sometimes called "Holding Zones," establish that no new development may take place in a given area for a period ranging from six months to two years, until a comprehensive plan or acceptable compromise development plan can be adopted. Fourteen states authorize some type of interim zoning regulations, and three states have similar authority for subdivisions. Florida allows the adoption of interim regulations with respect to building codes. Interim regulations can be particularly helpful in a period of transition, when a municipality or county is attempting to prepare equitable regulations in the face of increasing development pressures or citizen controversy with respect to a hazard-prone area. Even without specific interim regulation authority, however, the zoning power generally allows for the designation of low-density special permit zoning districts, which can serve a similar purpose if adopted prior to protracted controversy surrounding a site or development plan.

Sensitive land uses - In addition to the general procedural and substantive regulations discussed above, detailed application of regulations to certain sensitive land uses can be directly applicable to natural hazard mitigation(such as the siting of power plants in hurricane, earthquake, and other hazard zones). In addition, some zoning and subdivision regulations specifically exempt uses such as public utilities or agriculture. Procedurally, such exemptions can offer precedent for excluding important land uses from natural hazard mitigation policy based on land use criteria.

From state subdivision enabling authority, four states exclude certain public utilities. These exemptions are significant because, as Kusler [1976] points out, public utility uses such as roads, bridges, and levees are major offenders in blocking flood flows. They can also pose threats in an earthquake and other extreme natural events. Seventeen states exempt agricultural uses from subdivision regulation, and the same number (although not the same states) exempt them from zoning regulations. Agricultural fills, dikes, fences, and buildings also may block floodways and are subject to flood damage; and they can be hazards should an earthquake or tornado occur.

The subdivision of large lots, often over 2-1/2 acres, is subject to regulation in only 29 states. If large lots are exempt, fewer regulatory measures can be applied to sensitive areas.

Non-conforming land uses, defined by the ASPO Model Zoning Ordinance [1966] as lots, structures, or uses lawful before the zoning ordinance was passed but which would be prohibited or restricted under the ordinance, are exempt from zoning regulations in 38 states. Such uses can pose particular hazards in an extreme natural event because the uses are generally unspecified: thev tend to be older, unharmonious uses conflicting in intensity and scale with permitted uses in the zoning district. They may exist essentially unregulated until a natural disaster removes them, but in the meantime they affect development patterns and influence risk levels in surrounding areas.

Although exemptions of these uses from zoning and subdivision controls may be supportive of equity, in avoiding the imposition of hardship on farmers and marginal business, and although they may mitigate certain practical difficulties in land use management by allowing greater flexibility, they do reduce the effectiveness of natural hazard mitigation regulations.

Other sensitive uses regulated by some states include, first, inland wetlands. Twenty-two states either have established uniform permit procedures for these areas, or uniform regulations. All eligible states (a total of 30) are participating in the federally-funded coastal zone management program authorized by the Coastal Zone Management Act of 1972. Second, 34 states have the authority to determine the siting of power plants and related facilities. This is an important land use tool particularly with respect to earthquake mitigation. And third, 13 states have established regulations for the identification and designation of areas of critical state concern, such as environmentally-fragile areas.

In addition to the above policies, another important land use regulatory measure which can affect natural hazard mitigation is the requirement of permits for certain types of development. Five states currently have such broad legislation. Similarly, 24 states have "coordinated incremental planning," or a state-established mechamism to coordinate state land use problems. And nine state <u>require</u> their local governments, not merely authorize them, to establish a mechanism for land use planning through zoning, a comprehensive plan, and a planning commission.

Related to the direct regulation of land use are the financial policies which support certain land use configurations. For example, the unmitigated transfer of agricultural land to suburban land on the outskirts of urban areas, resulting partly from increased assessments of peripheral agricultural land, can have serious consequences for a coordinated and comprehensive planning effort. At this time, 42 states have developed tax measures designed to give property tax relief to owners of agricultural or open space lands. A similar policy could help to regulate lands subject to hazards such as landslides, or along a seismic fault, subject to appropriate development by the property owners.

Kusler and the CEQ report on those states which have authorized the adoption of flood plain regulations by state agencies. They indicate that thirty states have adopted regulations which may offer models for more general hazard mitigation measures. Finally, Kusler discusses those states which have included specific flood hazard regulations in various land use measures. A total of 39 states have zoning enabling legislation, and 34 states have similar language for subdivision control. The most common regulatory measure is the power to secure "safety from flood."

State Coastal Zone Regulations

In addition to statewide authority for natural hazard mitigation, several states have developed regulation relating specifically to the coastal zones adjoining the oceans and the Great Lakes. These activities have been supported by the Federal Coastal Zone Management Act of 1972.

As noted by Platt [NOAA, 1976] California, Washington, and Rhode Island have pioneered the concept of state coastal zone management. While there are major differences between the three states'coastal zone management programs, several common features may be identified. First, relevant planning areas consist of entire shorelines, not simply discrete landforms or problem areas. Second, administration is largely a state function with specific responsibilities delegated to certain local and regional entities (in the case of California and Washington). Third, state coastal authority extends inland to embrace activities and physical features associated with the coastline.

These programs may, according to Platt, be readily adapted to incorporate new perceptions of natural hazards. The Rhode Island Coastal Management Council, for example, denies permits for development on "undeveloped" beach areas and seeks to limit construction on dunes or beaches anywhere in the state. [See Figure 7-7]

Shoreline Zoning

Similar to the above approach is "shoreline zoning" as practiced in Minnesota, Wisconsin, Michigan, and Maine. Here, local governments must adopt land use regulations for their river and lake shoreline areas or such regulations will be adopted on their behalf by the state. In either case, administration of regulations remains with the local government.

State Flood Plan Regulations

New York has adopted mandatory flood plain zoning measures for all communities with recognized flood hazard areas. Eleven other coastal states, indicated in Figure 7-6, have adopted other forms of state-level flood plain management legislation.

Critical Areas Programs

The Model Land Development Code proposed in 1975 by the American Law Institute, suggested that states assume particular responsibility for "critical areas", by physical, cultural, economic or aesthetic criteria. As applied to coastal zone management, the critical areas approach is more restrictive geographically than the techniques described above, according to Platt. Critical areas programs have been adopted by Maine, Minnesota, Maryland, Florida, North Carolina, and Oregon.

Coastal Wetland Programs

Several states rely on their coastal wetlands permit program for CZM purposes, according to Platt [NOAA, 1976]. With the recent attention given to the importance of coastal wetlands in the ecological food chain, and the extent of their loss due to development along the Atlantic and Gulf coasts, many states have implemented coastal wetland programs.

	COMPREHENSIVE COASTAL OR LAND USE	SHORELAND ZONING	STATE FLOOD-PLAIN REGULA-TIONS	CRITICAL AREAS	COASTAL WETLANDS	SETBACK OR ENCROACHMENT LINES	BEACH AND SHORE PRESERVATION
Alabama	a						
Alaska							
California	b		x				
Connecticut			x		x	x	
Delaware	c				x		x
Florida	d			x		x	x
Georgia					x		
Hawaii	e	x	x			x	
Illinois							
Indiana							
Louisiana					x		
Maine		x	x	x	x		
Maryland	f		x	x	x		x
Mass.					x		
Michigan		x	x				
Minnesota		x	x	x	x		
Miss					x		
N.H.					x		
New Jersey	g		x		x		
New York			x		x		
N.C.	h		x	x	x		
Ohio							
Oregon	i			x			
Pa.							
R.I.	j				x		
S.C.							
Texas					x		
Virginia					x		x
Washington	k		x		x		
Wisconsin		x	x				

[a] Ala. Coastal Zone Development Act of 1973.

[b] Calif. Coastal Zone Conservation Act of 1972 (Final Plan adopted August, 1976).San Francisco Bay Conservation and Development Commission Act of 1969.

[c] Del. Coastal Zone Act of 1971.

[d] Florida Land and Water Management Act of 1974.

[e] Hawaii State Land Use Zoning Act.

[f] Md. State Land Use Act of 1974

[g] N.J. Coastal Area Facilities Review Act of 1973.

[h] N.C. Coastal Area Management Act of 1974.

[i] Ore. Land Conservation and Development Act of 1973.

[j] R.I. Coastal Management Act of 1971.

[k] Wash. Shoreline Management Act of 1971.

Source: Rutherford Platt, "Legal Aspects of Natural Hazards Regulations in the Coastal Zone," p. B-7 in NOAA [1976]

Figure 7-6. State Laws Relating to Coastal Hazard Mitigation

While most state programs regulating wetlands are based on their ecological value, Platt asserts that such areas serve to mitigate the effects of coastal flooding and erosion. Wetlands absorb the energy of coastal storms and dampen tidal surges in estuaries. The filling and development of such areas not only destroys this effect but expose the resulting new structures to direct assault by wind and waves.

Mandatory Setbacks

A mandatory setback or "encroachment line" may be legally imposed to restrain all further development of fill within a specified distance of a body of water. In Connecticut, encroachment lines have been established to protect the 100-year floodplain of portions of the Connecticut River and certain other streams.

Great Lakes states are turning to mandatory setbacks as a response to severe erosion occurring due to high lake levels. Michigan is proposing a statewide setback for lakeside development equivalent to thirty years of erosion (the average term of a mortgage). Illinois is considering a 100 year erosion setback, a distance of possibly 200 feet along its "North Shore" bluffs.

Development Moratoria in Coastal Areas

Most of the measures described above require extensive research and planning studies as a prerequisite to final implementation, notes Platt. Accordingly, some states have adopted an interim period of control through state legislation to be superseded by a final plan. This has been the case in Washington, California, New York and Florida.

Building Code Policy and Authority

As with land use policy, building codes have traditionally been a local government concern. In his survey of flood-related statutory authority, Kusler found that only 23 states had adopted one building code to be used by all governments, or otherwise regulated building code provisions over the entire state. Twelve of these states specifically authorize flood hazard regulations, and four states extend building code authority of municipalities ot extraterritorial zones. Field and Rivkin [1970], note that over 15,000 localities issue building permits, and approximately 8000 have their own building code, either based on a national code or developed locally.

Four national model building codes are available, from which states or local governments may choose rather than develop a local code. The four code associations are influential in different parts of the country, although there is some overlap. (Figure 7-7) Field and Rivkin [1975] note:

> The International Conference of Building Officials (ICBO) claims is in the West, Building Officials and Code Administrators (BOCA) in the Northeast, and Southern Building Codes Congress (SBCC) in the South. In the North Central region, BOCA and ICBO actively compete against each other for city members. American Insurance Association (AIna), creator of the National Building Code, is active in three regions, but has no penetration in the West. AInA, unlike the other three code associations, is not an association of building officials. Established in 1905, AInA created the National Building Code as part of their underwriting procedures for ascertaining risk of insurance losses due to fires. Overall, model codes are most evident in the South and West.

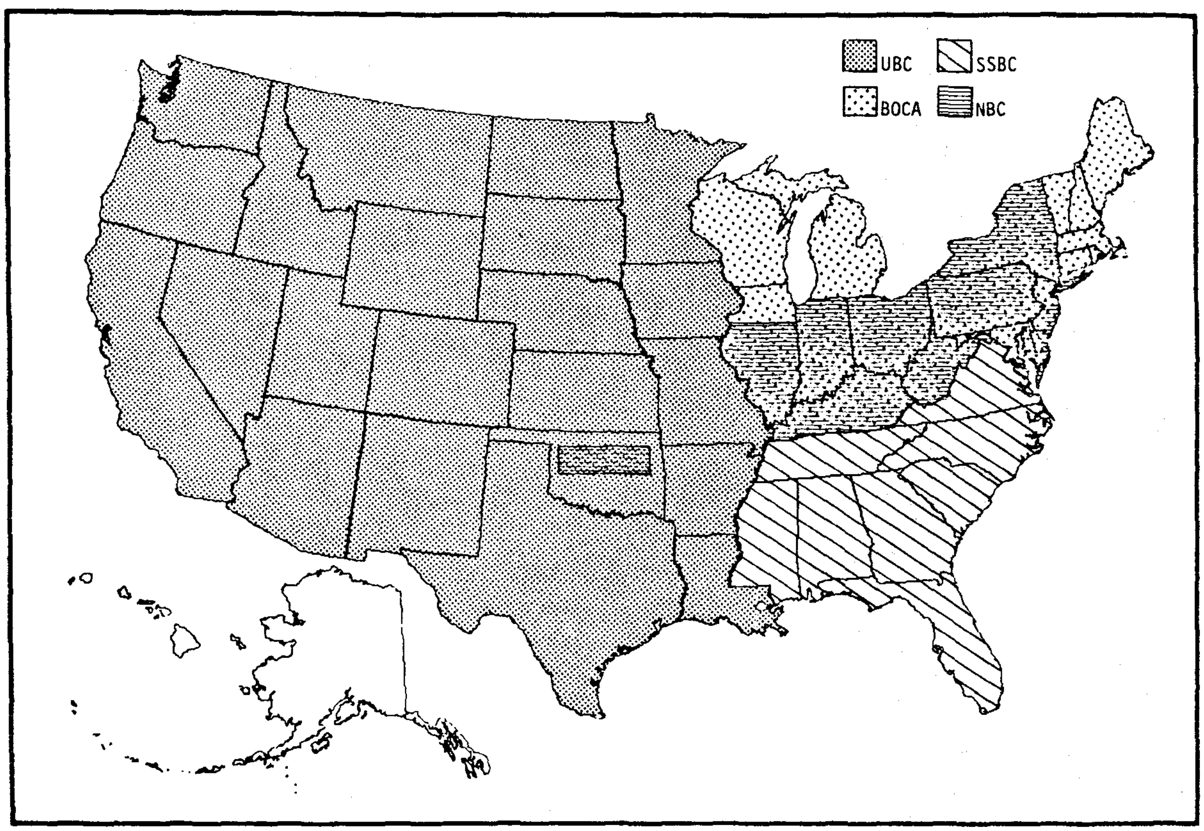


Figure 7-7. General Building Code Application by State

In 1970 Field and Ventre [repeated in Field and Rivkin, 1975] surveyed 919 cities in the United States with respect to building codes. At that time 73% of the cities in the survey based their code on one of the four national model codes. State based codes, themselves often based on one of the four model codes, were used by 1.3% of the cities, and locally-drafted codes by 10.8%. Only 2.2% of the cities surveyed,all of them small, reported having no building code. The results of this survey are presented in Table 7-6. Figure 7-8 identifies the code utilized by cities over 100,000 population in 1965.

Wind

Although building code policy can be important for the mitigation of several natural hazards, their widest application has been in preventing wind damage, including hurricane winds, and earthquake damage. The four model codes specify minimum wind loads for design, in terms of minimum wind pressure for various heights above ground level. None of these codes provides for tornadoes.

The methodology and design wind pressures vary among the four model building codes. The BOCA code wind provisions specify a single set of wind pressures that vary with height. The other three codes set forth several sets of wind pressures that vary with height; the set that is applicable for any given location depends upon the exptected magnitude of extreme winds for a given level of risk (such as once in 100 years).

The National Building Code has patterned its wind provisions after the recommendations of the American National Standards Institute [ANSI] A58-1-1972 Building Code [1972]. First the basic wind speed must be identified for a municipality; this is accomplished by means of a map which has superimposed upon it isotachs or contours of the basic wind speed for a return period of 100 years. This map, first developed by Thom [1968], is shown in Figure 7-9. Design wind pressures are determined from the code for the appropriate basic wind speed.

The Southern Standard Building Code (SSBC) of the Southern Building Code Congress also utilizes Thom's 100-year wind speed map to determine the wind speed for a given locality. Wind load pressures are specified in the SSBC code for various values of the basic wind speed. The pressures specified in this code are how-

Classification	Number of Cities Reporting	AInA (1)	ICBO (2)	SBCC (3)	BOCA (4)	State (5)	Locally Drafted Code (6)	No Code in Effect (7)
Total all cities	919	12.2%	31.3%	14.9%	15.1%	13.5%	10.8%	2.2%
Population Group								
Over 500,000	12	0.0	33.3	0.0	25.0	0.0	41.7	0.0
250,000–500,000	12	8.3	50.0	25.0	0.0	8.3	8.3	0.0
100,000–250,000	59	3.4	27.1	25.4	15.3	13.6	15.3	0.0
50,000–100,000	111	8.1	39.6	15.3	16.2	16.2	4.5	0.0
25,000–50,000	225	9.3	34.2	11.6	16.9	13.8	13.8	0.4
10,000–25,000	429	16.6	29.8	15.6	13.1	12.6	10.0	2.3
5,000–10,000	61	13.1	16.4	14.8	23.0	16.4	4.9	11.5
Less 5,000	10	0.0	30.0	0.0	10.0	20.0	20.0	20.0
Geographic Region								
Northeast	185	22.2	1.1	0.0	32.4	21.6	17.3	5.4
North Central	249	10.8	22.9	0.4	27.7	14.9	20.5	2.8
South	241	18.3	2.1	56.4	4.1	14.1	3.7	1.2
West	244	0.0	91.8	0.0	0.0	5.3	2.9	0.0
City Type								
Central	149	6.7	29.5	24.8	14.8	12.8	11.4	0.0
Suburban	414	11.1	33.6	7.2	20.0	12.8	14.0	1.2
Independent	340	16.5	28.5	20.6	9.7	13.8	6.5	4.4
Form of Government								
Mayor-Council	240	17.1	15.0	6.7	20.4	19.6	18.8	2.5
Council-Manager	625	10.2	38.9	17.6	12.8	11.5	7.4	1.6
Other[1]	54	13.0	16.7	20.4	18.5	9.3	14.8	7.4

[1] Includes: Cities with commission government, with town meeting, and with representative town meeting.

Source: Field and Rivkin [1975], p. 43

KEY:	MODEL CODE ASSOCIATION	MODEL BUILDING CODE
AInA	American Insurance Ass.	National Building Code (NBC)
ICBO	International Congress of Building Officials	Uniform Building Code (UBC)
SBCC	Southern Building Code Congress	Southern Standard Building Code (SSBC)
BOCA	Building Officials and Code Administrators	Basic Building Code (BOCA)

Table 7-6. Building Code Distribution in the United States

CITY	BUILDING CODE
Akron, OH	Local
Alameda, CA	UBC
Albany, NY	Local
Alhambra, CA	UBC
Allentown, PA	BOCA
Amarillo, TX	UBC
Atlanta, GA	Local
Austin, TX	UBC
Baltimore, MD	Local
Baton Rouge, LA	NBC
Bay City, MI	UBC
Beaumont, TX	SSBC
Berkeley, CA	UBC
Binghamton, MY	NBC
Birmingham, AL	SSBC
Boston, MA	Local
Bridgemport, CT	Local
Brockton, MA	Local
Buffalo, NY	Local & State
Burbank, CA	UBC
Cambridge, MA	Local
Camden, NJ	BOCA
Canton, OH	Local
Cedar Rapids, IA	UBC
Charleston, SC	NBC
Charleston, WV	Local
Charlotte, NC	State
Chattonooga, TN	SSBC
Chicago, IL	Local
Cicero, IL	Local
Cincinnati, OH	Local
Clevelan, OH	Local
Columbus, GA	SSBC
Columbus, OH	Local & State
Compton, CA	UBC
Corpus Christiy, TX	SSBC
Dallas, TX	UBC
Dayton, OH	BOCA
Deartur, IL	NBC
Denver, CO	?
Des Moines, IA	Local
Detroit, MI	BOCA
Duluth, MN	?
Durham, NC	State
East Orange, NJ	Local
El Paso, TX	SSBC
Elizabeth, NJ	NBC
Erie, PA	BOCA
Evanston, IL	BOCA

CITY	BUILDING CODE
Evansville, IN	Local
Flint, MI	Local
Fort Worth, TX	UBC
Fresno, CA	UBC
Gary, IN	Local
Glendale, CA	UBC
Grand Rapids, MI	BOCA
Greenville, SC	SSBC
Hammond, IN	BOCA
Harrisburg, PA	Local
Hartford, CT	Local
Houston, TX	UBC
Huntington, WV	UBC
Indianapolis, IN	State
Irvington, NJ	NBC
Jacksonville, FL	NBC
Kalamazoo, MI	UBC
Kansas City, MO	Local
Kenosha, WI	State & Local
Knoxville, TN	SSBC
Lakewood, OH	Local
Lawrence, MA	Local
Lexington, KY	NBC
Little Rock, AK	UBC
Long Beach, CA	UBC
Los Angeles, CA	Local
Louisville, CA	NBC
Medord, MA	Local
Memphis, TN	Local
Miami, FL	South Florida
Milwaukee, WI	Local
Minneapolis, MN	UBC
Mobile, AL	SSBC
Montgomery, AL	SSBC
Mt. Vernon, MY	NBC
Nashville, TN	SSBC
New Haven, CT	?
New Orleans, LA	UBC
New York, NY	Local
Newark, NJ	Local
Norfolk, VA	Local
Oakland, CA	UBC
Ogden, UT	UBC
Oklahoma City, OK	NBC
Omaha, NE	?
Peoria, IL	?
Philedelphia, PA	Local
Phoenix, AZ	Local
Pittsburg, PA	Local
Pittsfield, MA	Local
Pontiac, MI	BOCA
Portland, OR	Local

CITY	BUILDING CODE
Portsmouth, VA	SSBC
Providence, RI	BOCA
Pueblo, CO	UBC
Racine, WI	Local, ref to NBC & BOCA
Reading, PA	Local
Richmond, CA	UBC
Richmond, VA	Local
Riverside, CA	UBC
Roanoke, VA	NBC
Rochester, NY	Local
Rockford, IL	Local
Sacramento, CA	UBC
St. Louis, MO	BOCA
St. Paul, MN	NBC
Salt Lake City, UT	UBC
Sant Antonio, TX	UBC
San Bernadino, CA	UBC
San Diego, CA	UBC
San Francisco, CA	Local
San Jose, CA	UBC
San Mateo, CA	UBC
Santa Monica, CA	UBC
Schenectady, NY	Local
Scranton, PA	?
Seattle, WA	UBC
Shreveport, LA	SSBC
Somerville, MA	?
South Bend, IN	BOCA
South Gate, CA	UBC
Spokane, WA	UBC
Springfield, MA	Local
Stanford, CT	Local
Stockton, CA	UBC
Syracouse, NY	State
Tacoma, WA	?
Tampa, FL	Local
Toledo, OH	Local
Tulsa, OK	NBC
Utica, NY	Local
Washington, DC	Local
Wichita, KA	UBC
Wichita Falls, TX	Local
Wilmington, DE	BOCA
Winston-Salem, NC	State
Woonsocket, RI	NBC
Worchester, MA	State
Yonkers, NY	Local
York, PA	BOCA

Source: Directory of Safety & Construction Codes USA States & Cities by Karl O. Siemon, Code Publishing Co., N.J., 1965

Figure 7-8. Code Used in Cities Over 100,000 Population in 1965

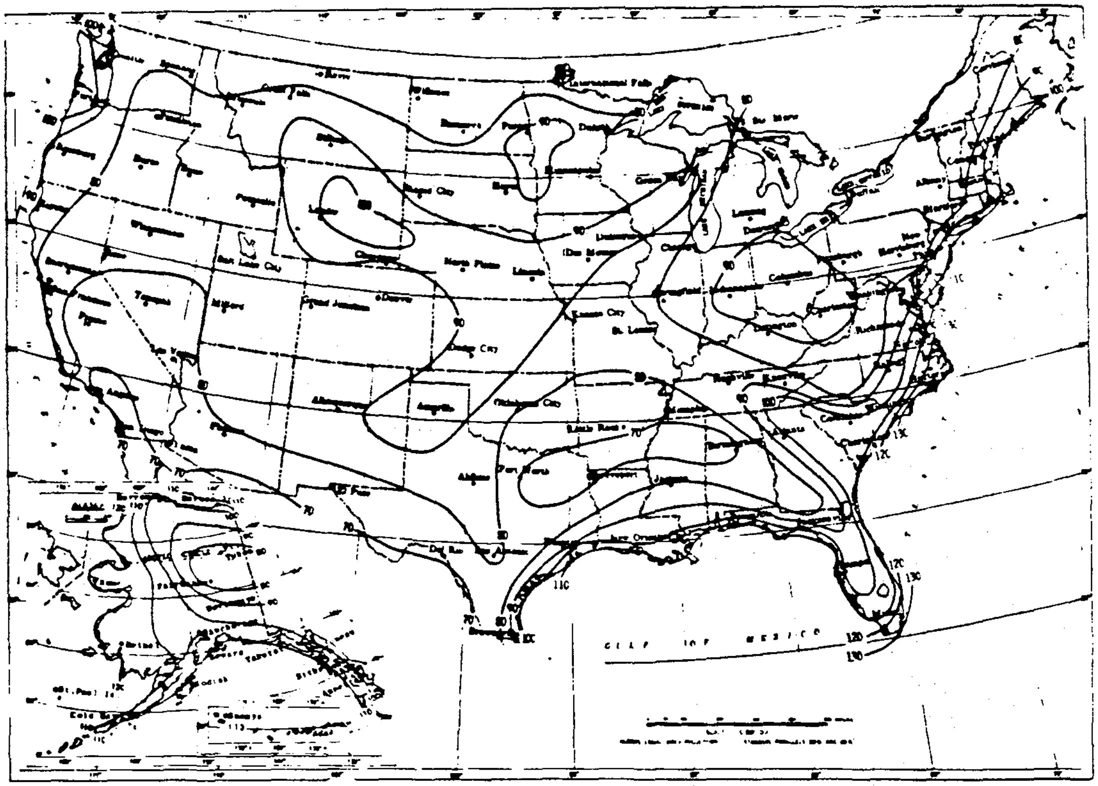


Figure 7-9. Basic Wind Speed, V_{30}, Miles per Hour.
National Building Code (1976 Edition).

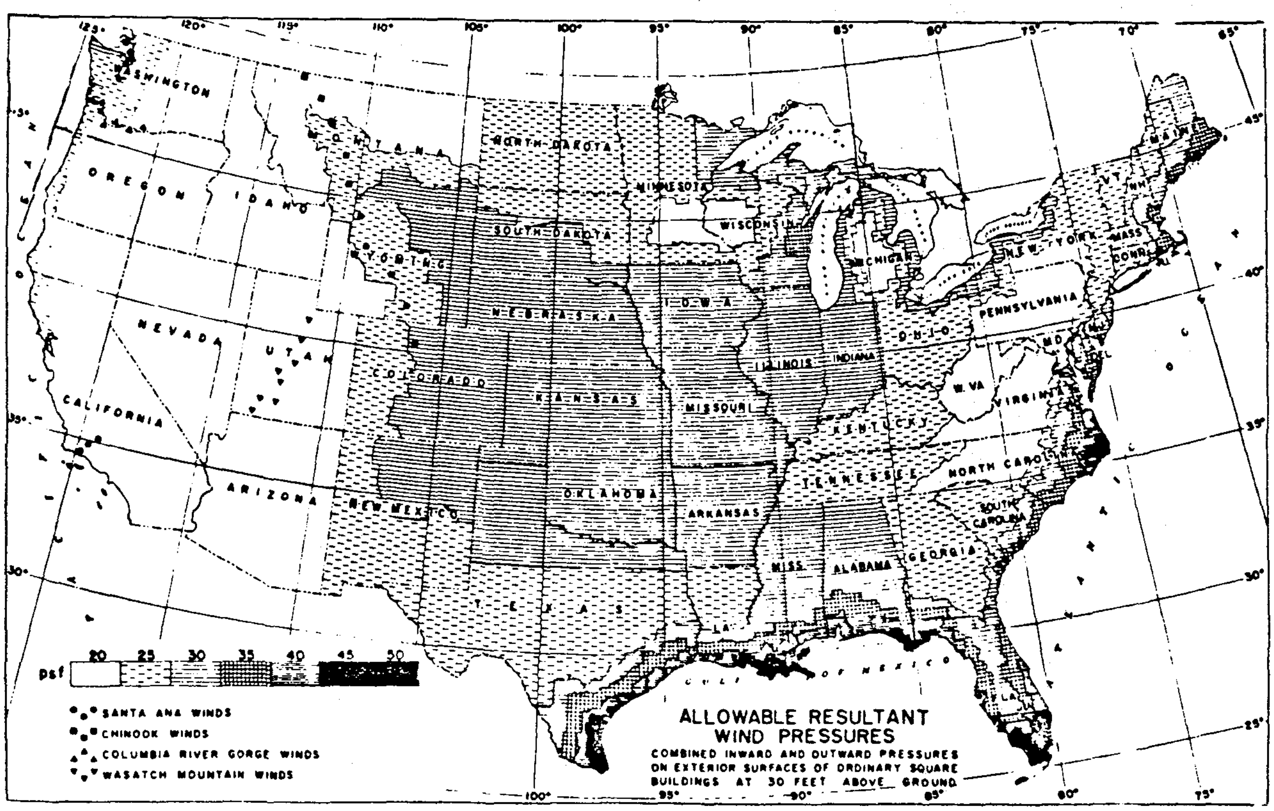


Figure 7-10. Allowable Resultant Wind Pressures
Uniform Building Code (1976 Edition)

ever, different than those specified by the NBC.

As with the National Building Code and the Southern Standard Building Code, the Uniform Building Code also utilizes a map; however, the map defines minimum allowable wind pressures at a reference height of 30 feet [Figure 7-10]. From this, the wind pressures for different height zones are determined from a table in the UBC. The 1976 UBC wind provisions have changed little over the years and are essentially the same as found in its 1961 edition [Buoh and Bihr, 1975].

The method by which the wind pressures are used to obtain design forces is the same for the building code with the exception of the NBC. The pressures obtained by the BOCA, SSBC, and UBC may be used directly for design while the pressures found by the NBC must be modified by external pressure coefficients before design. For purposes of this study, the UBC has been chosen as the reference code.

To obtain an approximate equivalency in design wind loads among the model codes, the wind pressures specified by the BOCA code must be multiplied by the factors shown in Table 7-7, to arrive at the same wind forces that would be calculated by the method used by UBC. Tables 7-8, and 7-9 are the multiplication factors that need to be applied to the wind pressures of the NBC method to obtain the equivalent design wind forces by the UBC. Tables 7-10, 7-11, and 7-12 show the multiplication factors to obtain equivalency of the SSBC to the UBC design wind forces.

Of the four model codes, the BOCA code specifies just a single set of wind pressures. These pressures are generally significantly less than that which would be required by any of the three other codes. BOCA does not seem to recognize that higher design pressures may be required. Section 716.0 of the Code does state that"... for building and structures located .... in geographical regions subject to higher wind loads than herein specified, the design wind load shall be determined by the prevailing conditions". However, no performance standards or guidance are provided as to what the wind loads should be or what regions may be subject to higher wind loads.

The UBC, although allowing for geographical variation in the minimum allowable wind pressures, is based on wind information that was collected through 1951. This suggests that a re-evaluation of the UBC wind requirements may be in order so that more current wind data are included.

UBC WIND PRESSURE ZONE (psf)						
20	25	30	35	40	45	50
1.25	1.50	1.90	2.10	2.35	2.70	3.00

Table 7-7. Multiplication Factors to BOCA Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for All Heights

NBC BASIC WIND SPEED (mph)	UBC WIND PRESSURE ZONE (psf)						
	20	25	30	35	40	45	50
50	1.90	2.20	2.80	3.00	3.50	3.90	4.40
60	1.40	1.60	2.00	2.20	2.50	2.90	3.30
70	1.00	1.15	1.44	1.60	1.80	2.05	2.35
80	0.75	0.85	1.07	1.15	1.35	1.50	1.70
90	0.55	0.65	0.85	0.90	1.05	1.20	1.30
100	0.45	0.52	0.65	0.72	0.85	0.95	1.05
110	0.40	0.45	0.55	0.60	0.70	0.77	0.85
120	0.30	0.36	0.45	0.50	0.57	0.65	0.72
130	0.26	0.30	0.36	0.42	0.47	0.55	0.60

Table 7-8. Multiplication Factors to NBC Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for Heights Less than 100 Feet

NBC BASIC WIND SPEED (mph)	UBC WIND PRESSURE ZONE (psf)						
	20	25	30	35	40	45	50
50	1.60	2.10	2.50	3.00	3.30	3.70	4.00
60	1.20	1.60	1.90	2.20	2.40	2.80	3.00
70	0.90	1.10	1.30	1.50	1.70	1.90	2.10
80	0.65	0.85	1.00	1.10	1.30	1.45	1.60
90	0.55	0.65	0.80	0.90	1.00	1.15	1.25
100	0.40	0.50	0.65	0.70	0.80	0.90	1.00
110	0.35	0.43	0.50	0.60	0.65	0.75	0.80
120	0.30	0.35	0.42	0.50	0.57	0.65	0.70
130	0.25	0.30	0.35	0.40	0.47	0.55	0.60

Table 7-9. Multiplication Factor to NBC Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for Heights Greater than 100 Feet

SSBC BASIC WIND SPEED (mph)	UBC WIND PRESSURE ZONE (psf)						
	20	25	30	35	40	45	50
70	1.25	1.45	1.80	2.00	2.30	2.60	2.90
80	0.95	1.12	1.40	1.55	1.75	2.00	2.25
90	0.75	0.90	1.13	1.25	1.42	1.60	1.80
100	0.60	0.72	0.90	0.98	1.15	1.30	1.45
110	0.50	0.60	0.75	0.82	0.95	1.07	1.20
120	0.43	0.50	0.62	0.68	0.78	0.90	1.00
130	0.36	0.42	0.53	0.58	0.67	0.76	0.85

Table 7-10. Multiplication Factors to SSBC Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for Heights Less than 100 Feet

SSBC BASIC WIND SPEED (mph)	UBC WIND PRESSURE ZONE (psf)						
	20	25	30	35	40	45	50
70	1.10	1.40	1.70	2.00	2.20	2.50	2.70
80	0.85	1.10	1.30	1.50	1.65	1.95	2.10
90	0.67	0.85	1.00	1.20	1.30	1.50	1.65
100	0.55	0.70	0.80	0.95	1.08	1.25	1.35
110	0.45	0.57	0.68	0.80	0.87	1.00	1.10
120	0.38	0.47	0.56	0.67	0.74	0.85	0.95
130	0.32	0.40	0.50	0.57	0.63	0.73	0.80

Table 7-11. Multiplication Factors to SSBC Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for Heights Between 100 and 500 Feet

SSBC BASIC WIND SPEED (mph)	UBC WIND PRESSURE ZONE (psf)						
	20	25	30	35	40	45	50
70	1.00	1.25	1.45	1.70	1.90	2.20	2.40
80	0.75	0.95	1.10	1.30	1.45	1.65	1.80
90	0.57	0.75	0.87	1.00	1.15	1.30	1.45
100	0.47	0.60	0.70	0.85	0.95	1.05	1.15
110	0.38	0.50	0.60	0.70	0.75	0.87	0.96
120	0.33	0.42	0.50	0.57	0.65	0.75	0.82
130	0.28	0.36	0.42	0.48	0.55	0.62	0.70

Table 7-12. Multiplication Factors to SSBC Wind Pressures for Approximate Equivalency to UBC Design Wind Loads for Heights Greater than 500 Feet

As the NBC and the SSBC codes both rely on Thom's map of 100-year return period basic wind speeds (which is based on extreme wind data collected through 1965) these two codes would seem to be the most up-to-date in relation to the determination of design pressures. However, the SSBC design method after utilizing design pressures would be close to that used by the BOCA and UBC codes. The NBC code does seem to be a little more advanced in its recognition or inclusion of pressure coefficients which account for pressure variations on the exterior of the building.

In addition to the wind provisions of the four model codes, local communities subject to severe wind levels have adopted building requirements to meet their local needs. For example, the Corpus Christi, Texas, building code specifications for wind standards were developed from their experience with previous hurricanes.

Figure 7-11 shows an approximate relationship among the wind pressure criteria of the standard codes. The precise relationship between code design level forces is somewhat more complex because the relative level of wind loads presented in various codes is a function of building height, wind speed, and experience.

In addition to the wind provisions of the standard building codes, certain hazard prone states have developed extensive building code standards for natural hazard mitigations. The Texas Coastal and Marine Council [1976; 1977] and Lesso [1976] analyzed the natural hazard threat along the Texas Gulf coast and estab-

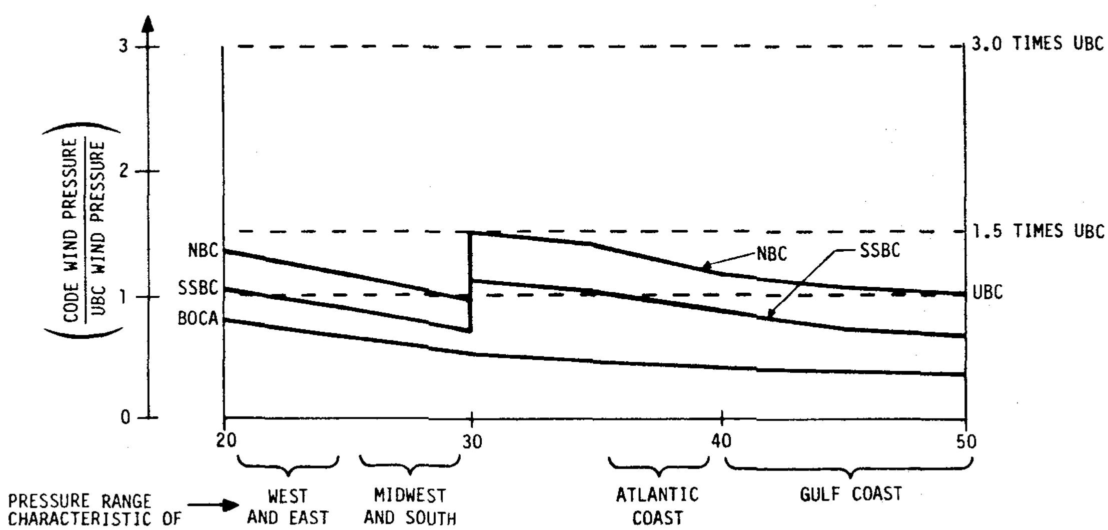


Figure 7-11. Uniform Building Code Wind Pressure (Psf)

lished procedures for determining the degree of exposure to "reasonable probable" hurricane conditions. The council also developed a model minimum building standard designed to reduce hurricane damage if implemented as an adjunct to a standard building code.

Earthquake

The repeated occurrence of earthquake has also prompted governments in earthquake-prone areas to incorporate lateral-force criteria in building regulations. According to Slosson and Krohn [1977], after the 1933 Long Beach earthquake the Uniform Building Code was amended in 1939 to include earthquake-resistant design. In addition, the 1933 Long Beach earthquake led to the passage by the California legislature (School House Safety Act) and the Riley Act.

The Field Act required that school buildings be designed to sufficiently withstand earthquakes so that no harm would come to the occupants. Steinbrugge et al., [1978] state that:

> The Act's principal provisions require that all construction plans be prepared by qualified persons and that the designs be checked by an independent State agency. The independent review is generally considered the most important part of the Field Act, aimed at catching design errors or omissions, or other inadequacies that might not provide adequate earthquake resistance, before construction contracts are let.
>
> Another important aspect of the Act requires construction to be continuously inspected by a qualified person retained by the school board to see that all of the requirements of the plans are carried out. Moreover, all parties, including the architect, engineer, inspector, and contractor, must submit verified reports stating that the approved plans and specifications were complied with in construction.
>
> Knowledgeable observers consider the Field Act eminently successful in assuring reasonable compliance with acceptable levels of earthquake resistance. Almost all Field Act schools have performed well in all earthquakes since the law's passage. While some experts anticipate that some Field Act buildings will be severely damaged in future great earthquakes, there is agreement that injury or life loss will, nevertheless, be greatly reduced because of the Act's requirements.

The Riley Act extended the requirements for earthquake-resistant design to commercial and industrial buildings.

Following the 1971 San Fernando earthquake in California, a series of new pieces of legislation were adopted by the California legislature, (A summary of this activity is contained in Figure 7-12). In particular, according to Steinbrugge, et al., [1978]:

> California's Hospital Act of 1972 was drafted using the Field Act (applying to schools) as a guide. The law requires that design work for new hospitals, or substantial additions to or alterations of existing hospitals, be done by qualified specialists. The design must be thoroughly reviewed for safety by the Office of the State Architect.

Although the program has generally been regarded as successful, general administrative problems have arisen, such as the definition of "hospital" and other terms, the permit fee structure, and the appropriate level of construction standards.

The 1971 earthquake also precipitated amendments to the City of Los Angeles Building Code for residential structures requiring revisions in the design and construction of diaphragm sheathing, veneer ties, framing, reinforcing of concrete in masonary chimneys, anchorage of water heaters, and regulations related to cutting and notching of walls and studs. It is anticipated that these changes will greatly improve the safety and stability of residential structures with a cost increase of less than 1%.

The City of Los Angeles has also recently enacted code changes for multi-story structures. These changes require site analysis and dynamic analysis with safety requirements for all additions to a structure.

Expansive Soil

Of the four model building codes, only the Uniform Building Code specifically mentions expansive soils. Section 2904 specifies a standard test to determine a soil expansion index. In areas with expansive soil, the code only specifies that there shall be a "special design consideration."

BILL NUMBER	SUMMARY
SENATE BILL 351 (1971-72)	MODIFIED SECTION 63502 OF THE GOVERNMENT CODE TO REQUIRE THAT A SEISMIC SAFETY ELEMENT BE PREPARED BY EACH CITY AND COUNTY AND INCLUDE IN THE GENERAL PLAN. THE ELEMENT IS TO CONSIST OF AN IDENTIFICATION AND APPRAISAL OF SEISMIC HAZARDS AND A DEFINITION OF THE RISK FOR THE COMMUNITY.
SENATE BILL 479 (1971-72)	(SECTION 15002.1 OF THE EDUCATION CODE) REQUIRED GEOLOGICAL AND SOIL ENGINEERING STUDIES FOR ALL-PROPOSED SCHOOL SITES TO PRECLUDE THE SITING OF A SCHOOL IN ANY LOCATION WHERE THE GEOLOGIC/SEISMIC CHARACTERISTICS ARE SUCH THAT THE CONSTRUCTION EFFORT REQUIRED TO MAKE THE SITE SAFE FOR OCCUPANCY IS ECONOMICALLY UNFEASIBLE. IT ALSO STATED THAT NO SCHOOL BUILDING SHALL BE CONSTRUCTED OR SITUATED ON THE TRACE OF AN ACTIVE GEOLOGICAL FAULT.
SENATE BILL 519 (1971-72)	SENATE BILL 519 (SECTION 15000 OF THE HEALTH AND SAFETY CODE) ESTABLISHED BASIC REGULATIONS FOR SITE EVALUATION, THE DESIGN AND CONSTRUCTION OF HOSPITALS. IN ADDITION, A TECHNICAL BOARD WAS CREATED WHICH WAS COMPRISED OF LICENSED PROFESSIONALS IN ALL OF THE INVOLVED AND ALLIED SUBJECT FIELDS.
SENATE BILL 520 (1971-72)	A FAULT HAZARD ZONE ACT WHICH REQUIRES THE EXAMINATION OF EACH SITE TO ASSURE THAT NO STRUCTURE OF HUMAN OCCUPANCY IS BUILT ASTRIDE OR ON AN ACTIVE FAULT. IN ADDITION, REQUIRES DISCLOSURE OF THE PRESENCE OF THE FAULT ZONE IN ALL REAL ESTATE TRANSACTIONS.
SENATE BILL 1114 (1973-74)	REQUIRES THAT ANY SCHOOL BUILDING CONSTRUCTED ON AN ACTIVE FAULT BEFORE 1957 SHALL BE SUBJECT TO REPLACEMENT AT ANOTHER LOCATION IN ACCORDANCE WITH THE FIELD ACT. REMAINS IN EFFECT ONLY UNTIL DECEMBER 31, 1974.
SENATE BILL 1729 (1973-74)	CREATED THE SEISMIC SAFETY COMMISSION WHICH IS RESPONSIBLE FOR ENCOURAGING RESEARCH: GATHERING, ANALYZING, AND DISSEMINATING INFORMATION: COORDINATING GOVERNMENTAL SEISMIC SAFETY ACTIVITIES; SETTING GOALS AND PRIORITIES; AND OTHER ACTIVITIES IN CONNECTION WITH EARTHQUAKE HAZARD REDUCTION.
SENATE JOINT RESOLUTION 63 (1973-74)	SJR 63 REQUESTS THE PRESIDENT AND THE CONGRESS OF THE UNITED STATES TO ASSURE THE PEOPLE OF CALIFIORNIA THAT ACTION WILL BE INITIATED TO ESTABLISH A PROGRAM FOR ABATEMENT OF SEISMICALLY HAZARDOUS FEDERALLY OWNED STRUCTURES IN THE STATE OF CALIFORNIA, AND THAT THE PROGRAM WILL CONSIDER THE ELEMENTS OF ABATEMENT PROGRAMS IN EXISTENCE IN CALIFORNIA.
SENATE BILL 2422 (1973-74)	SB 2422 AMENDS THE ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT (SB520) TO REQUIRE THE STATE GEOLOGIST TO DEFINE "NEW REAL ESTATE DEVELOPMENT" AND "STRUCTURE FOR HUMAN OCCUPANCY."
ASSEMBLY BILL 2015 (1973-74)	PERMITS CONTINUED USE OF SCHOOL BUILDINGS WHICH ARE NOT IN COMPLIANCE WITH THE FIELD ACT STRUCTURAL STANDARDS (EARTHQUAKE SAFETY) AFTER JUNE 30, 1975, IF AUTHORIZED BY THE STATE ALLOCATION BOARD AND THE WORK ON REPAIR, RECONSTRUCTION, OR REPLACEMENT OF SUCH BUILDINGS HAS COMMENCED. PROHIBITS AUTHORIZATION FOR CONTINUED USE OF SUCH BUILDINGS AFTER JUNE 30, 1977. AN URGENCY MEASURE.
ASSEMBLY BILL 4140 (1973-74)	REQUIRES THAT BUILDINGS OR STRUCTURES BE DESIGNED AND CONSTRUCTED TO RESIST EARTHQUAKES (AND HIGH WINDS) ACCORDING TO THE UNIFORM BUILDING CODE, NOT AS FORMERLY CALLED FOR IN THE CALIFORNIA ADMINISTRATIVE CODE. ALSO ALLOWS THE DIVISION OF CODES AND STANDARDS OF THE DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT TO ENFORCE THE EARTHQUAKE PROTECTION CHAPTER OF THE HEALTH AND SAFETY CODE.
SENATE BILL 1950 (1975-76)	PROVIDES IMMUNITY FROM LIABILITY TO A PUBLIC ENTITY OR PUBLIC EMPLOYEE ACTING IN RESPONSE TO AN EARTHQUAKE EMERGENCY OR WHENEVER AN EARTHQUAKE EMERGENCY APPEARS REASONABLY IMMINENT.
SENATE BILL 2059 (1975-76)	ABOLISHED THE STATE BUILDING STANDARDS COMMISSION AND REPLACES IT WITH THE DEPARTMENT OF BUILDING SAFETY, THE COMMISSION OF BUILDING SAFETY, AND A BOARD OF BUILDING REGULATION APPEALS. ESTABLISHES THE COMMISSION AS THE SOLE STATE AGENCY WITH AUTHORITY TO ADOPT BUILDING REGULATIONS. AFTER JULY 1, 1977, NO STATE AGENCY EXCEPT THE COMMISSION WOULD BE PERMITTED TO ADOPT ANY BUILDING REGULATIONS
ASSEMBLY BILL 3684 (1975-76)	WAIVES THE REQUIREMENT UNDER SENATE BILL 479 FOR GEOLOGIC AND SOIL ENGINEERING STUDIES PRIOR TO ACQUIRING SITES FOR SCHOOL BUILDING PURPOSES, EXCEPT FOR SITES WITHIN AN ALQUIST-PRIOLO SPECIAL STUDIES ZONE OR WITHIN AN AREA DESIGNATED AS BEING HAZARDOUS IN THE LOCAL SEISMIC SAFETY ELEMENT.
AB 4278 (1975-78)	GAVE THE GOVERNOR EMERGENCY POWERS TO DEAL WITH DISASTERS, IN ACCORDANCE WITH THE FEDERAL DISASTER RELIEF ACT OF 1974, UPON HIS PROCLAMATION THAT AN EMERGENCY EXISTS. THIS BILL GIVES HIM ADDITIONAL EMERGENCY POWERS IF THE PRESIDENT DECLARES A MAJOR DISASTER EXISTS.

Figure 7-12. Recent California Experience in Earthquake Hazard Reduction Legislation (1971-1976)

Landslide

Many landslides are man-induced chiefly because of a lack of adequate slope grading codes or enforcement of existing codes. In Contra Costa County, California, approximately 80% of the landslides are man-related [Nilsen and Turner, 1975]. The annual loss in the United States from landslide activity has been estimated to be at least $370 million [Slosson and Krohn, 1976].

The effectiveness of adequate grading codes as a deterrent against man-induced landslides is exemplified in the City of Los Angeles. Very high property losses and some lives lost from landslides and mudflows during the 1950's and 1960's in California prompted the introduction of local codes and land use regulations. The heavy rains of January 1952 caused approximately $7.5 million damage within the City of Los Angeles. During the heavy rains of 1952 and 1955, loss or near loss of approximately 150 homes was due to the Portuguese Bend landslide in Palos Verdes Hills, Los Angeles County. Damages sustained at Portuguese Bend as well as other areas of Los Angeles brought about the first grading codes in 1952.

The grading codes were subsequently updated and improved by the City of Los Angeles one year after the heavy rains in 1962,which caused flood, landslides, and mudflows. This final code change in 1963 greatly reduced the loss or risk factor from man-induced landslides.

The new grading codes were given a test by the severe rains of 1969. An analysis of data collected by the Department of Building and Safety of the City of Los Angeles after the 1969 storm strongly suggests that landslide damage can be essentially eliminated by the proper use of scientific and engineering analysis in conjunction with realistic codes properly enforced. Statistics of damage to hillside homes from the 50-year storm showed clearly the value of engineering geology and soils engineering studies in preventing loss, (Table 7-13). The estimated cost of engineering geology and soils engineering studies in a typical housing tract is between $50 and $100 per home, which is economically sound when compared to the average loss per home inflicted by the 1969 storm.

Construction dates and, legal requirements		Number of homes built on hill-side sites	Damaged homes Number	Percent of total (%)	Total damage	Average Cost prorated for total number of homes
Pre – 1952	No legal requirement for soils engineering or engineering geology studies	10,000	1040	10	$3,300,000	$300
1952 – 1963	Soils engineering studies required. Minimum engineering geology studies.	27,000	350	1.3	$2,767,000	$100
Post – 1963	Extensive engineering geology and soils engineering studies required	11,000	17	0.15	$ 80,000	$ 7

Data from City of Los Angeles Department of Building and Safety, 1969

Table 7-13. Landslide and Flood Damage to Hillside Homes During January and February 1969 (50-Year Storm Event). Los Angeles County, CA

Problems with Local Building Code Variations

The standard building code tend to address natural hazards at certain generalized levels, but local variations in hazard levels and attitudes toward the role of building codes tend to vary widely. Certain areas subject to extreme levels of natural hazards have developed specific policies to protect the citizenry from those hazards, specifically in the area of potential wind damage reduction through the use of wind-resistant building standards of the Texas Coastal and Marine Council, the Southern Florida Hurricane Standards, and the building code guidelines for National Flood Insurance. The Federal Insurance Administration requires all living areas of flood-prone residences in a municipality participating in the National Flood Insurance Program to be at or above the base flood level as indicated on the FIA's flood insurance rate map. [Department of Housing and Urban Development , 1976]. However, building codes as a general rule tend not to include detailed treatment of natural hazards mitigation measures. According to Field and Rivkin [1970], part of the problem is the number of standards with which we have to deal and the derivation of those standards:

> ... there are literally thousands of standards in use today covering all aspects of housing. One estimate placed it between 13,000 - 14,000, most having been developed by the various buildin trade associations. These associations, some 400 - 500 in 1968, represent specialized product groups. For example, the interest of the cast iron soil pipe manufactures are represented through the Cast Iron Soil Pipe Institute, and wood interests are handled by the National Forest Products Association. While these associations conduct, through their membership, the actual research and testing to develop specific standards, certification comes from one of these standardization associations. Two of these, the American National Standards Institute and the American Society for Testing Materials, adopt standards through what is termed the consensus process. Special committees, representing industry and public interests, meet to consider a proposed standard and eventually reach a consensus on the acceptability of the proposed standard.

Performance standards are extremely important in establishing objective criteria for product use in building codes. However, the trade associations are often considered by some to be "closed shops". Thus, building codes are partially the result of supplier group influence and partially the function of local building code enforcement professionals who themselves have generally been recruited from the building trades.

Conclusions

Project constraints prevented the study team from independently acquiring detailed data concerning organizational operations, budgetary and expenditure levels, and internal federal, state, and local governmental plans concerning the management of natural hazards. For many of these details we have been dependent on previously published documents and sources of information which are readily available to the professional and lay public. Nonetheless, the following conclusions seem justified on the basis of the evidence at hand:

1. The U.S. Congress already has authorized the Executive Branch to design and implement policies and programs which could provide most of the needed ingredients to a comprehensive, well-integrated, balanced, and rational national-level natural hazards management program.

The disaster relief act of 1974 delivered to the Executive Branch the principal legislative authorizations necessary to the design and partial implementation of a comprehensive, well-integrated, balanced, and rational national-level natural hazards management program.

The act defines "major disaster" as meaning "any hurricane, tornado, storm, flood, high-water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snow storm, drought, fire, explosion, or other catastrophe in any part in the United States...". The act authorized the president [Section 201 (A)] to establish "a program of disaster preparedness", utilizing "services of all appropriate agencies", such program to include "plans for mitigation, warning, emergency operations, rehabilitation, and recovery" as well as plans for "training ... annual review of programs ... coordination of federal, state, and local preparedness programs... application of science and technology.. research." The president was required by the act to "provide technical assistance to the states in developing comprehensive plans and practicable programs for preparation against disasters, including hazard reduction, avoidance, and mitigation...[Added]. The act further required the president to "conduct annual reviews of the activities of federal agencies and state and local governments providing disaster preparedness and assistance, in order to insure maximum coordination and effectiveness of such programs and ... from time to time report thereon to the Congress." [Section 316]

Section 406 of the act requires that, as a "condition of any loan or grant made under the provisions of this act, the state or local government shall agree that the natural hazards in the areas in which the proceeds of the grants or loans are to be used shall be evaluated and appropriate action shall be taken to mitigate such hazards, including safe land-use and construction practices in accordance with standards prescribed or approved by the President after adequate consultation with the appropriate elected officials of general purpose local governments, and the State shall furnish such evidence of compliance with the section as may be required by regulation." Section 201 (C) of the act states that presidentially authorized planning grants to the states shall be used for the "development of plans, programs, and capabilities for disaster preparedness and prevention" and requires states to submit, to the president, plans which shall "set forth a comprehensive and detailed state program for preparation against and assistance following emergencies and major disasters". The president is authorized by Section 601 of the act to "prescribe such rules and regulations as may be necessary and proper to carry out the provisions of this act" and further authorizes the president to "exercise any power or authority conferred on him by any section of this act either directly or through such federal agency or agencies as he may designate".

Thus, the Disaster Relief Act of 1974 provided the executive branch with several specific requirements which it was to meet and further authorized and encouraged action by executive agencies to develop plans for mitigating the risks associated with exposures to potential disastrous natural hazards, including all of those examined in this study, with the single exception of expansive soils. Interestingly, the United States Water Resource Council Report on a "Unified National Program for Flood Plain Management" was submitted to the president in response to Section 1302 (C) of the National Flood Insurance Act of 1968 [PL 90-448] and does not indicate that the proposals in any way relate to the congressional charge upon the president under the terms of the Disaster Relief Act of 1974. Beyond the general authorities contained in the Disaster Relief Act of 1974 are, of course, the specific mandates and authorizations contained in the National Flood Insurance Act of 1968 [PL 90-448], the Flood Disaster Protection Act of

1973 [PL 93-234], the National Dam Inspection Program [PL 92-367], the Coastal Zone Management Act of 1972 [PL 92-583], and the Earthquake Hazards Reduction Act of 1977 [PL 95-124]. Statutory authorizations which underpin the programs of the National Oceanic and Atmospheric Administration, the National Science Foundation, the U.S. Soil Conservation Service, the U.S. Corps of Engineers, and other agencies also butress the existing legal capacities for hazard-related program planning and development operations within the federal establishment. Also, of course, the specific authorizations contained in the Environmental Education Act and other similar statutes provide a basis for extensive implementation of technology transfer, and attention-focusing policies in respect to natural hazards management.

2. Both past and current federal natural hazard management policies involve substantial and increasing externalization of the costs produced by natural hazard risk takers.

By June 1975, the multi-decade cost of flood control-projects completed under the supervision of the U.S. Corps of Engineers totaled $10.2 billion (in non-constant dollars). The overwhelming fraction of these costs were incurred between 1936 and 1975. Direct federal expenditures for disaster assistance totaled more than $4 billion between 1953 and 1973 [See Table 7-5] and from $158 to $173 million per year are currently being expended from tax revenues to subsidize flood insurance programs [See Table 7-4]. Of course, additional substantial sums are being expended for the annual operation and maintenance of existing area flood protection facilities, for technology development and transfer operations, for administration of disaster relief and other hazard-related programs, and for other similar purposes. The evidence seems to be that annual expenditures for this mix of program purposes are increasing and will continue to increase for several decades to come. Although owners and renters of property within natural hazard zones clearly experience, and will continue to experience the major fraction of losses sustained as a result of their exposures, it also is clear that no-risk-takers residing outside these zones also are bearing a significant fraction of the cost of the risk taking.

As noted above, project constraints prevented a detailed study of the present and probable future magnitude of the externalization of costs that result from natural hazard risk taking, but the subject clearly is one deserving of future detailed study.

3. In comparison with national annual expected losses from natural hazard exposures, comparatively small sums currently are being expended by the national government for technology development, technology transfer, and public attention-focusing purposes.

Both the cost associated with natural hazard exposures and the costs associated with efforts to mitigate those hazards are sufficiently large to warrant the cost-effective creation of a national data base adequate to the demands of rational and compassionate decision-making by local, state, and federal policy makers as well as informed policy implementing activities by professionals and administrators in both the public and private sector. Weighed against these costs, federal expenditures for research, technology transfer, and attention-focusing purposes apparently have been rather small. Thus, White & Haas [1975] have observed that "natural hazards research in our nation is spotty, largely uncoordinated, and concentrated in physical and technological fields." Although the Earthquake Hazards Reduction Act stimulates needed research in respect to that hazard, it is not at all clear that other areas of knowledge deficiency of equal or greater importance have been appropriately funded.

Little documentation is required to assert that large technical assistance requirements are faced by understaffed and only marginally professional building regulation and planning agencies at local levels and even by the larger state level or regional planning staffs. Fully adequate and completely documented damage and damage reduction algorithms have yet to be developed for most of the major hazards, and hazard zone identification criteria having high predictive quality are all too sparce. Significant sources of non-catastrophic loss, such as expansive soils, have yet to be addressed through the kind of empirically sound and policy-useful research that the magnitude of the annual losses would suggest to be warranted The marginal cost-benefit relationship associated with incremental upward or downward shifts in model building code requirements has only been inadequately addressed. All too many hazard planning and policy influencing documents generated at the federal level or funded by federal agencies are essentially "qualitative" in their approach to assessments of hazard risks and program payoffs, suggesting the sad state of the data base in this field.

4. There are numerous federal points of leverage which may be employed to support future action-forcing policies at the federal level in respect to the management of natural hazards.

Without considering their political feasibility, there are numerous statutes and federally-financed programs which could be utilized to support the future adoption of action-forcing policies, and programs by the federal government. Adoption of appropriate hazard mitigation laws, regulations, and plans by state and local units of government can be made a condition for award of federal disaster relief funds, federal flood insurance subsidies, subsidies for hospitals, and other health care facilities enumerated in the National Health Planning and Resources Development Act [PL 93-641], and could further be made a condition for award of federally-supported or guaranteed mortgages under the programs administered by such agencies as the Veterans Administration, the Farmers Home Administration, and the Federal Housing Administration. It is more than conceivable that such disparate action-forcing policy could focus on land use planning and zoning, other forms of hazard zone avoidance, building codes, notifications of hazard exposures to buyers at time of transfer of property title, etc. (See discussion of legal constraints in Chapter 8).

5. State and local action to promote the avoidance of development in natural hazard zones, to reduce the vulnerability of persons and property within such zones, and to otherwise mitigate the risks associated with natural hazard exposures has been spotty, of widely-varying quality, and inconsistent with the dimensions of natural hazard exposure losses.

Chapter Eight

CONSTRAINTS ON PUBLIC HAZARDS-MANAGEMENT POLICY-MAKING

Introduction and Summary

However severe or limited the impacts of natural hazard exposures may be, and however deficient or efficacious past public policies may have been in respect to such exposures, future public policy-making in this field will be constrained by a mix of legal, socio-political, and economic factors.

The nature and importance of each of these three sets of constraints is reviewed in this chapter.

Legal Constraints on Public Hazards Management Decision-making

In terms of their domestic functions, governmental entities within the United States are viewed by scholars as engaging in the development and implementation of four broad types of public policies: allocative or distributive; regulatory; structural; and redistributive [Lowi, 1964; Salisbury, 1968; Anderson, 1975; Jones, 1977].

Distributive policies are those which confer benefits or services, which determine what types of service is to be provided to whom, where, and when. Nineteenth century land distribution policies of the federal government, as well as contemporary river and harbor improvements and agricultural and business subsidy programs, are exemplary of this class. On the other hand, redistributive policies are those which calculably are intended to transfer income or wealth from one or more groups of citizens or areas to other groups of citizens or areas. Such policies involve a "conscious attempt by the government to manipulate the allocation of wealth, property, rights, or some other value among broad classes or groups in society." [Ripley and Franklin, 1976]. Structural policies establish organizations and systems for disbursing benefits (for implementing other policies) and provide guidelines for allocating such benefits [Salisbury, 1968].

In contrast to the above, regulatory policies are those that are intended to establish and enforce constraints on citizens and private organizational decision-making and behavior.

Within the field of natural hazards management, examples of all four types of public policies may be found at federal, state, and local levels. In general, the power of all three levels to engage in these several classes of policy-making is not questioned by the courts, but the specific details of any given policy in any class may be so questioned. For example, government's power of eminent domain is not questioned, in general, by the courts, but in any specific case this exercise may be found to be legally indefensible. For example, the public condemnation of a private beach-bordering home for the explicit purpose of later transferring title to the property to the son of the condemning jurisdiction's chief executive probably would be found to involve an illegal use of governmental power. Similarly, although a sea wall may be constructed by a governmental entity to protect a whole community or neighborhood, the courts are likely to look with disfavor on such action if the property to be protected is that of a single property-owner. However, so long as legitimate "public purpose" can be shown, the legal constraints on the making of the distributive, structural, and redistributive policies by federal and state governments are few, indeed.

In respect to local governments, the constraints have primarily to do with the fact that, in the eyes of the courts, these units of government are subordinate creatures of the states and - in general- are vested only with such authority as that which has expressly been given to them by state constitutions or by state law making bodies. Thus, the ability of local units to make "structural" policies concerning how they shall organize and staff to engage in the delivery of state sanctioned "distributive" services may be constrained by state-imposed "structural" requirements or by the absence of expressly granted authority from the state for the local unit to engage in such decision-making. In respect to all forms of policy-making by local units of government, Mandelker [1963] has observed that "local governments must find the source of their powers either in the home-rule enabling provisions of state constitutions, or in specific enabling statutes".

Dillon's rule frequently is offered as a general guide to an understanding of the powers of local government.

The rule states:

> It is a general and undisputed proposition of law that a municipal corporation possesses and can exercise the following powers and no other: First, those granted in express words; second, those necessarily or fairly implied in, or incident to, the powers expressly granted; third, those essential to the declared objects and purposes of the corporation--not simply convenient, but indispensable. Any fair, reasonable doubt concerning the existence of power is resolved by the courts against the corporation, and the power is denied. . . . [Mandelker, 1963]

At all three levels of government, special problems are posed by efforts to engage in regulatory policy-making. Such efforts involve two types of legal questions: one concerned with the general authority of the "regulating" governmental entity to act in respect to the focal matter and parties, the other concerned with such external constraints on the exercise of the authority as those that specify that the regulations must be reasonable and not arbitrary.

All regulatory legislation at state and local levels of government may be traced ultimately to the "police power" of the states. Although this phrase is incapable of precise definition, the term has been "used and given shape by the courts in the course of thousands upon thousands of adjudications. The term identifies valid governmental actions undertaken to protect the health, safety, and welfare of the community" [Krier, 1970]. At the federal level, the "working equivalent" of the "police power" is the grant of power contained in Article III, Section 8, of the U.S. Constitution.

At both state and federal levels, regulatory policy-making is constrained by specific constitutional prohibitions, such as those contained in the Fifth and Fourteenth Amendments to the U.S. Constitution. These amendments, respectively, state that: "no person shall be . . . deprived of . . . property without due process of law; nor shall private property be taken for public use without just compensation". The Fourteenth Amendment goes on to state that ". . . no state shall . . . deny to any person within its jurisdiction the equal protection of the laws".

These prohibitions have much potential impact on the making of natural hazard management regulatory policies. Such policies can be viewed as being expressed in several possible forms: (1) as land-use planning or zoning legislation, (2) as seller disclosure requirements, (3) as housing or building code standards, (4) as constraints on insurance systems, (5) as legislation establishing controls over subdivision practices, (6) as requirements that permits or licenses be secured from regulatory entities before construction or operation of facilities or before engaging in specified activities, (7) as legislation, regulations, or orders that impose specific conditions on a citizen's eligibility to receive a public service, such as those that require recipients of federally-subsidized or guaranteed mortgages to demonstrate that the property in question meets specified wind resistance, building strength, or other standards.

Subdivision regulation arose in the United States with the demand for simplified land conveyancing. Eventually the simplified method came to be not only a convenient alternative, but a required procedure in certain circumstances. In either case, more is involved than conveyancing. Local governments have attached a variety of regulatory policies to subdivision approval. In general, these policies have sought to pass on infrastructure costs to developers (and therefore to the eventual occupants of the development). Accordingly, developers have been required to dedicate land for, and in some cases install, streets, parks, schools, etc. When this was impracticable, fees in lieu of dedication or installation have been imposed.

The principal disadvantage of subdivision regulation, particularly that which does not involve fees, has been its inflexibility and dependence on the developer. Dedication and installation requirements may be exacted only once. Other means must be employed to control subsequent development. Moreover, whether dedication and installation actually take place remains wholly at the discretion of the developer. If he chooses to abandon the project nothing can be done.

The means which have been adopted to make subdivision regulation serve purposes other than simplified conveyancing have an obvious relevance to hazard abatement. Just as developers can be required to provide for streets and parks, so responsibility for hazard abatement programs can be imposed on them. Thus, for example, special treatment of the land could be required to abate riverine flooding, storm surge, expansive soils and landslides. Similarly, installation of special facilities (like catchment basins) could be mandated.

The permits required to engage in construction have expanded enormously in recent years. These permits are multifarious. They include permits to build, to occupy, to make water or sewer connections, to have vehicular access to the street, etc. The land development control purpose served by these permits is obvious. The existence of building and occupancy permits, for example, clearly enhances zoning and building code enforcement.

These construction-related permits can also be made to serve hazard abatement ends. They are in fact, in some areas of the United States, already used in hazard contexts. It is now usual in certain landslide prone areas of California to require a soil stability study as a condition of building permit issuance.

Building permits, and other appropriate permits, could also be conditioned on abatement actions like those mentioned in the above discussion of subdivision regulation.

Zoning was, of course, the forerunner in attempts to control land development. It has become so common that only a very brief description is necessary here. Zoning's principal thrust has been the segregation of incompatible uses. Uses thought to be entirely inconsistent, like most residential and industrial ones, have accordingly been separated most fully. Less inconsistent uses like residential and commercial ones, have called forth less rigid segregation.

Relative to subdivision regulation, zoning seems to offer greater temporal flexibility. As conditions change, zoning can change to meet them. The nature of subdivision regulation does not seem to permit this same accomodation to change, except on a project-by-project basis. All but very substantial subdivisions prompt discussions between regulators and developers. As a result, the regulatory purpose may be more effectively served. Zoning, however, prompts such discussions only when variances from the existing zoning are necessary--generally involving very substantial projects. In these cases, a common outcome is the imposition of exactions like those under subdivision regulation.

When variances are necessary, zoning can of course fulfill the same functions as subdivision regulation--both for hazard abatement and other purposes. Ordinarily, however, the most effective use of zoning in the hazard context is to foreclose hazard-sensitive activity in zones of high hazard risk. Thus, zoning has been already used to severely limit construction in areas subject to riverine flooding and storm surge; in general, only agricultural, recreation and park activities have been permitted. Restrictions like these, or other more appropriate ones, could, of course, be used to avoid activity in areas subject to the other natural hazards considered here. Seller disclosure requirements are widely imposed in modern economic life. In certain areas, like the issuance and sale of corporate securities, the requirements imposed are heavy. For others regulation is less intense, but still present. As in other areas. disclosure requirements are useful in the natural hazard context because they permit persons to rationally adjust their activity to the circumstances present. Such requirements can be imposed at several points. For example, there can be recorded in the land title records for areas of high hazard risk a notice of that risk. Persons entering into transactions involving land in such areas will accordingly be able to avoid or voluntarily assume it. Similar ends would be served by requiring brokers and other persons involved in the sale of land in areas of high hazard risk to apprise prospective buyers of its existence and extent.

Building codes have a history almost as long as zoning and need little introduction. They are intended to provide standards, often claimed to be minimal ones, for safe structures. Frequently, a distinction is made between building codes and housing codes, the former governing new construction and the latter existing structures. The standards of housing codes should presumably be, but are not always in fact, less onerous than those of building codes--since it is generally less expensive to incorporate a given feature into a new building than to alter an old one to conform.

Building and housing codes provide an obvious means for protection against natural hazards of all kinds. Standards can be varied to provide whatever degree of protection for buildings and their contents is considered desirable. Moreover these standards can be applied on a zonal basis. Standards for zones of high hazard risk can be made more severe than those for zones of lesser risk.

Insurance has long been used to mitigate financial loss to property owners (and those making funds available to property owners) from a variety of causes. In so doing it spreads the financial consequences of loss among a broad population of persons subject to loss. The risk-spreading effects of insurance are so attractive that it has even, in a variety of situations, been forced upon both insurers and persons subject to risk. In the area of automobile accident insurance, for example, some states have required automobile owners to carry such insurance as a condition to licensing their vehicles, and also have required insurance companies to insure all owners applying for it. The latter requirement is normally accompanied by permission for insurance companies to form a pool to insure high-risk owners.

The attractiveness of the financial loss mitigation and risk-spreading features of insurance are apparent in the natural hazard area. While it might not be possible to go so far as with automobile accident insurance, and thus require every property owner to carry a hazard insurance policy, nevertheless insurance coverage could be required under more limited circumstances--for example, almost any form of public assistance to the property owner might be conditioned on such insurance. Hazard coverage, in turn, could be a required insurance company offering. In fact, it already is in some states. In California, for example, insurance companies are required to offer fire insurance to owners of property in high risk areas.

All of these expressions of regulatory policy are subject to constitutional constraints.* The nature of these constraints is suggested by two polar hypothetical situations in which the constraints imposed by due process and equal protection on police power regulation are incompatible.

Situation I: John Doe, owner of a ten-acre tract surrounded recently by an about-to-be-completed residential development, maintains there a slaughterhouse. Twenty years ago when he bought the tract and built the slaughterhouse, the nearest residential development was five miles distant. The district including his

*For further discussion of the matters discussed in this section, see Bosselman, Collies and Banta, 1973; Hagman and Misczynski, 1978; Kusler and Lee, 1972; and Michelman, 1967.

ten acres has just been annexed to a city which has an ordinance classifying slaughterhouses as public nuisances and prohibiting their operation in predominantly residential districts. The city has just brought suit to enjoin operation of the slaughterhouse.

Situation II: Robert Roe is also the owner of a ten-acre tract surrounded recently by an about-to-be-completed residential development. He, however, has done nothing with the tract since he purchased it for speculation twenty years ago, maintaining its original condition as a partially wooded, gently rolling area of some natural beauty. The city which has recently annexed the district including his land has informed him that it may in the future be acquired as a park (although there are already several parks located in the district). In the meanwhile, it is classified as a "holding zone," which means that the land must be maintained as it is, with no construction of any kind permitted. In spite of this, and as the first step in his plan to make good on twenty years of hopes, Roe filed an application to subdivide for residential purposes. Upon denial of the application, he commenced suit to declare the holding zone invalid and require approval of his application.

As an initial matter it may be noted that both Situation I and II have certain things in common. In both cases that which the land owner seeks, to continue slaughtering animals or to turn his land into a residential subdivision, can be seen as harmful-- it would, in the one case, subject his neighbors to the smells and squeals of slaughtered and unslaughtered animals, and, in the other, deprive them of a pleasant vista and place to picnic. Therefore, that which the city seeks would be clearly beneficial. Looking however at Situation I and II from the standpoint of the landowners, rather than from that of his neighbors, that which Doe and Roe seek is beneficial--to continue supplying meat to a hungry world in the one case, and to furnish it with shelter in the other. Therefore, they argue, that which the city seeks is a positive harm.

In spite of these two-sided similarities in the two situations, it is reasonably clear that they would be decided differently by the courts. The use being made of his property by the landowner in Situation I would be said to constitute a public nuisance in that it impairs the health and welfare of his neighbors. Indeed, had the city not acted, they or one of them would have been able to enjoin the slaughterhouse as an unreasonable interference with their own uses. Any contention by the landowner that the city ordinance deprived him of, or took, property because his slaughterhouse was thereby rendered valueless would be rejected by the courts.

The landowner in Situation II, on the other hand, would very likely be successful in his litigation. The holding zone into which his land was classified would be said to constitute a taking without compensation under the Fifth Amendment--because it precludes any use by the landowner -- and to therefore require a declaration of its invalidity. Moreover, the invidious distinction between the development rights of other landowners in the neighborhood and those of the landowners would also be said to require a declaration of invalidity under the Fourteenth Amendment.

In the material which immediately follows, our overall concern is the justifications that would or could be given by the courts to support these differing results in Situation I and II -- and how hazard-related regulatory policies would fare under those justifications. This will involve an analysis of the relatively few Supreme Court decisions in the area and a review of other court decisions bearing more closely on other matters.

Tests of Constitutionality

Fifth Amendment

As emphasized above, regulatory policies involve an exercise of the state's police power. Constitutional exercise of that power, in the by now familiar litany (see, for example, Judicial Decision 13,20), calls only for findings that the "interests of the public require interference ("public purpose"), that the means chosen are "reasonably necessary for the accomplishment of the purpose" (reasonableness"), and that the means are not "unduly oppressive upon individuals" ("undue burden"). These findings are remarkably uncomplicated to state. Their application, however, particularly in the context of situations involving the use of property (thus bringing in the Fifth Amendment), has not always proved so simple. In the case of hypothetical situations I and II, above, for example, the findings seem to be of little value. Certainly in both cases a public purpose (protection of the public's health and welfare) is being served, and certainly the means employed (prohibition of the current harmful use in the case of Situation I, and the proposed one in the case of Situation II) are reasonably calculated to lead to fulfillment of that purpose. That the means are not unduly oppressive is less clear, but it is difficult to say they are more or less so in the case of one situation than the other.

The findings called for then do not seem of any particular value in precisely identifying situations, like Situations I and II above, in which the courts would predictably arrive at different results. Something else is apparently at work. In order to identify that "something else" we will examine a concrete application of the findings in a Supreme Court case decided more than fifty years ago. In spite of its age the case, Pennsylvania Coal Company v. Mahon (Judicial Decisions, 27), remains important--if not quite so decisive as it once seemed--probably because the majority opinion was written by one of the Court's most respected members, Justice Holmes.

Pennsylvania Coal was a case commenced by a homeowner, Mahon, seeking to enjoin the coal company from carrying on subterranean mining operations under his house. If continued, those operations would cause, as they had already caused to other property owners, subsidence of the land surface and consequent damage to buildings, and conceivably persons, there located. Mahon brought the action under the Pennsylvania statute prohibiting mining in such a way as to cause subsidence in urban areas. The statute had been enacted in response to widespread subsidence (the City of Scranton was said to resemble a battlefield "razed to the ground by shots from below"), and after a previous statute requiring support to be maintained artificially had failed to cure the problem. One other fact is worth noting, although it receives no explicit recognition in Holmes' rationale for the decision. It is that the coal company, in addition to owning the subsurface rights to minerals, was also the beneficiary of an agreement, made at the time Mahon's predecessor acquired the surface rights, under which any future claim for personal injury or property damage attributable to subsidence was waived. From at least a strategic viewpoint it would have been preferable had a homeowner other than Mahon, one not subject to such an agreement, commenced the suit. This, however, was unlikely. In the coal mining regions of Pennsylvania, it appears that land was generally held subject to such an agreement or the coal company was the owner of both surface and subsurface rights.

Preliminarily, we can say the same thing about the factual situation of this case as was said about the hypothetical Situations I and II. The findings required to sustain an exercise of the police power do not seem of any decisive impact. Indeed, this must be the case since the case's factual situation is less extreme that the polar Situations I and II, and the required findings are of little value there. Accordingly, what Holmes had to do to construct a decision premise was to fill out the meaning of these findings. Since the factual situation presented very little room for maneuver in the case of the first two findings -- public purpose and reasonableness -- it was on the third -- undue burden -- that he focused. He stated his test of undue burden as follows:

> Government hardly could go on if to some extent values incident to property could not be diminished without paying for every such change in the general law. . . . Some values are enjoyed under an implied limitation and must yield to the police power. But obviously the implied limitation must have its limits. . . . One fact for consideration in determining such limits is the extent of diminution. When it reaches a certain magnitude, in most if not all cases, there must be an exercise of eminent domain and compensation to sustain the act. So the question depends on the particular facts.

The "particular facts" which Holmes singled out to sustain his holding that the Pennsylvania legislation had excessively diminished "values incident to property" used by the coal company, and was therefore constitutionally invalid as applied to it, was the completeness with which the legislation wiped out the coal company's rights. It was the owner of only subsurface mineral rights, and the technology of the day apparently did not permit those rights to be economically exercised without surface subsidence. Legislation which forbad subsidence, therefore, just as effectively stripped the coal company of the benefits of its property as if it had prohibited mining completely.

Whatever may be thought of Holmes' test of undue burden, and we will consider it shortly, one may doubt its fulfillment in the situation of Pennsylvania Coal. Briefly put, his conclusion that the test was satisfied depends crucially on the uninvestigated, indeed unmentioned, state of technology at the time. Had it been shown that a technology was available, or was in the process of development and would shortly become available, permitting the coal company to mine underground without surface subsidence, it may be doubted that Holmes would so confidently have found its rights wiped out. We will return to an examination of some other implications of this point below.

Our evaluation of the merits of the test propounded by Holmes, that undue burden should be judged by extent of diminution, will be more effective if some of the other available tests are first brought in. Before doing this, however, we should clear some situations in which no test has been thought necessary. One of these involves physical occupation of the landowner's premises. Typical of this situation are cases in which state (or state authorized) activity, like the construction of a dam, has resulted in the premises being convered with water or some other substance so that any use of them is effectively precluded [See, for example, Judicial Decisions, 3, 21, 32]. The cases in which the activity is low and there are frequent airplane overflights may also be considered as instances of physical occupation [See, for example, Judicial Decisions, 14, 45]. Whatever the activity, however, its classification as physical occupation makes the search for the correct test of a constitutionally-sanctioned exercise of the police power irrelevant. Thus, physical occupation will trigger application of the taking clause of the Fifth Amendment and require the payment of compensation.

Another situation in which the constitutional boundaries of the police power have been thought to be irrelevant is that involving state regulation of nuisance uses. Typical are cases exactly inverse to those of the previous paragraph, cases of land uses that threaten or cause destructive, if only temporary, physical invasion of neighboring premises, including those resulting from smell diffusion as in the cases of a slaughterhouse. Examples are: maintaining a structure dangerous to passersby [Judicial Decisions, 5] or trees infested by a pest fatal to neighboring trees [Judicial Decisions, 22]. Just as nuisance use involves a factual inverse to the physical occupation cases, so is the conclusion of the courts generally the opposite. Such a use is (generally) not considered property of the kind protected by the Fifth Amendment. The qualification generally has been inserted here because the use of the coal company in Pennsylvania Coal appears to be characterizable as a nuisance. Yet the Supreme Court invoked the Fifth Amendment to preclude State regulation.

Most situations with which the courts have dealt, however, do not fall neatly in the category of physical occupations and nuisance uses. Certainly the regulatory policies relative to national hazards management are not so easily disposed of. We must, therefore, return to a consideration of the correct test of police power exercise.

As we have seen Holmes' test for distinguishing police power regulations imposing undue burden was extent of diminution. His test, however, did not pre-empt the field. Already present, and of continuing vitality today to judge from the extent it enters judicial opinions, was the harm/benefit test [See Freund, 1904, Section 511; Judicial Decisions, 24]. This makes the validity of regulations depend on their effect -- if they prevent harm to the public they are constitutionally sanctioned; if they instead provide public benefits, they are not and the appropriate means for supplying the benefit is eminent domain.

The harm/benefit test, it is clear, contains an early expression of the functionalist analysis of the state. The "preventing public harm" element of the test would lead to description of the government's exercise of power as a regulatory function. Its providing of a "public benefit" would, on the other hand, be seen as an exercise of the allocative or distributive function. Whether in the form of harm/benefit or functionalist analysis, however, there is a fundamental problem in using the test to determine constitutional validity. That problem was suggested in the above analysis of Situations I and II. It consists in a core reciprocity in most situations of police power exercise: that which is preventing public harm, from the standpoint of the state of the offended public, is simply providing a public benefit at private expense, from the standpoint of the person regulated. A similar reciprocity also exists in many situations concededly going beyond the police power and requiring eminent domain; when the state so restricts the use of the property as to effectively deny its owner any economic benefit, it thereby both provides the public benefit (at private expense) sought by the restriction and prevents the public harm that would result from the owner's proposed use.

On this analysis we cannot expect the harm/benefit test to yield satisfactory results in litigation involving the constitutionality of police power regulation. Public harms and public benefits are both generally present and the test does not tell us how to weight them or prefer one to another. The decision in situations like Situations I and II, indeed even in physical occupation and nuisance use situations, would therefore be completely fortuitous.

If the harm/benefit test is of no value in determining undue burden, what then of Holmes' test of extent of diminution? Clearly the test has an advantage over the harm/benefit formulation. It at least tells us what to look at. We are to consider the degree to which the "values incident to property" have been diminished by the regulation. Beyond this, however, no guidance is provided--other than that the "question depends on the particular facts". Holmes seems to have been sure that, at least on the particular facts of Pennsylvania Coal, there could be no doubt that his test was satisfied--all that the coal company owned had been effectively taken by the regulation. While we cannot, for the state-of-technology reasons outlined above, be so sure; nevertheless, the factual situation he supposed to exist would seem in fairness to require compensation. If physical occupation may not be employed to make use of the land owner's premises, then no more should that state be permitted the same result by completely precluding their use. This, of course, is what is being attempted in Situation II above. Instead of taking the land owner's premises for park purposes under eminent domain, the city seeks the same end through their inclusion in a holding zone.

Short of complete preclusion of use -- regulations achieving this effect, Situation II to the contrary, are probably not very common -- Holmes' test is not very decisive. We are instructed to look at the extent of diminution, but that is all. We are not told how to look at it. Should it, for example, be measured against the value of the property absent the police power regulation? And in that case, what should be done when the property is of no value but could be made to have some, absent the regulation? Or, to take another example, should extent of diminution be measured against the damage which could result without the regulation?

Consideration of the extent of diminution relative to value absent the regulation at issue has been relatively common in the reported cases. Some commentators have tried to extract a decision premise from this consideration, concluding that a finding of invalidity is apt to follow from evidence showing a decline of more than two-thirds [Krasnowiecki and Strong, 1963]. That this conclusion is less than compelling is suggested by Supreme Court approval (in a case decided before Pennsylvania Coal, but during Holmes' tenure) of regulations causing a decline of more than 90% [Judicial Decisions, 15], and by the failure of other commentators to find any regular pattern [Anderson, 1968, p. 101].

Were the proper standard for measuring extent of diminution agreed to be the value absent regulation, we would still not be free of problems. A situation increasingly common in the 1970's illustrates the problem. Suppose the property sought to be regulated is under water or otherwise unusable. Absent the regulation, the property owner might be able, by filling or other appropriate action, to give the property a substantial value; but, it has none as it stands. How then are we to evaluate the constitutionality of a regulation seeking to perserve the natural state of the property? One answer to this question is that the situation, as described, improperly characterizes the property in its natural state as valueless. Ownership of property implies the right to alter it, and that right is valuable even if taken by itself the property is not. Under this interpretation, the value absent regulation standard remains unambiguous. It can be applied without difficulty to a submerged-land situation. The courts, however, have apparently not been accepting this analysis. Recent regulations involving submerged land have been uniformly sustained against constitutional attacks even though they preclude any alternative by the landowner (see, for example, Judicial Decisions, 8, 13, 31, 36). The decisions have stressed, among other factors, the fact that the property as it stands is not commercially usable.

Value absent the regulation, however, is not the only standard derivable from Holmes' opinion in Pennsylvania Coal. Holmes himself provided a hint that the appropriate standard was instead the damage ensuing in the absence of regulation. His opinion notes, without further comment, that Pennsylvania Coal was a case brought by the owner of a "single private house." It may be then that one of the factors influencing the decision was the balance of damage to Mahon's house were the regulation struck down, and product unproduced by the coal company were it upheld -- or, more appropriately, the balance of property damage from all subsidence and total unproduced coal. Some legal commentators have thought that this was, or ought to have been, the test intended by Holmes. None, however, has gone so far as the economist, R.H. Coase, in his famous article on social cost

[Coase, 1960]. There Coase examines, from the standpoint of optional resource allocation, situations of reciprocal damage which ordinarily underlie police regulations or suits seeking to end nuisances. He concludes that, in a world free of transaction costs, the content of the decision premise adopted by the courts in nuisance suits is immaterial from the standpoint of the resource allocation optimum -- as long as a clear premise is adopted. Whatever the premise, the behavior of the parties will be determined not by it, but by the balance of damages. Thus, if the demand and cost schedules facing the owner of a factory involving a nuisance use is such that all damage to others caused by remaining in business can be passed on to the consumers of the product, then the factory will remain in business even though the courts declare it a nuisance.

Coase goes on to point out that this happy result is not common in the world as it is, one in which transactions are normally costly, or in situations involving exercise of the police power. In such cases, the behavior of the parties will be determined by the decision premise of the courts or the police power regulations. Whatever the balance of damages, the parties will be constrained, either economically by costly transactions or legally by the state, to go along with the premise of the regulations.

From the standpoint of optimal resource allocation, therefore, police power regulations and the constitutional rules governing their validity can have a decisive impact. Accordingly, Coase suggests that the proper judicial test in suits involving regulations (or nuisance uses) is optimality. The party representing the largest potential loss should carry the day.

Sound as Coase's conclusions may be in guiding us to an allocative optimum, they are less persuasive in a legal context. We can question both the role which they would assign to the courts, and whether they properly frame the issue which is, or ought to be, of concern to the courts. The role assigned to the courts is questionable because it may be doubted that a litigated case is the proper context for the determination of costs and benefits.

More important than the role of the courts, however, is Coase's questionable framing of the issue before them in litigating involving the police power. Adding some additional facts to Situation II above will provide an excellent example of this. Let us suppose that the municipal regulations at issue there result in an allocative optimum. More fully, the supposition is that the damages which would be suffered by the landowner's neighbors were his property developed are greater than the diminution of value he would suffer were development blocked. Under these circumstances the proper result under Coase's test is a decison sustaining the regulations. But this, it should be noted, is a result going far beyond the scope of the limited balancing standard of Pennsylvania Coal. It permits, as that standard would not, the landowner to be effectively deprived the benefits of his property through complete preclusion of use. And it permits this because Coase's analysis and the test derived therefrom explicitly exclude a factor that must be considered by the courts: the fairness of depriving a few of their property so that others may benefit more. Putting this another way, Coase was solely concerned with rules likely to generate an allocation of resources yielding the largest total product, and not with the redistributional consequences of those rules. In passing on police power regulations, on the other hand, the courts are frequently called on to consider both optimality and fairness. This is not, of course, an inevitable part of their deliberations. The legislature could provide for compensation to regulatory victims. Were it to do so, few judicial problems would remain. When, as is often the case, it does not do so, the courts must struggle with resolving the ultimately unresolvable. To prefer optimality in that struggle, as Coase would do, is no better answer than an unreserved preference for individual property rights. Resolution cannot be purchased so cheaply.

Apart from the problem it raises in defining the boundary between constitutional and unconstitutional exercises of the police power, the damage absent regulation standard also poses a measurement problem. It is one thing, as in Situation I, to balance an unpleasant environment against unproduced food, but what if a further consequence of the activity sought to be regulated were personal injury or death? Unless life can be valued on the same basis as property, that standard is literally inapplicable. In Pennsylvania Coal, Holmes would have had to face this problem, sudden subsidence being after all as dangerous to life as to property, but for the fact that the Coal company had given notice of its prospective underground operations. The case, therefore, involved only competing property interests. Had it involved personal injury or death, we can be sure Holmes' opinion would have been quite different.

Before turning to a more specific consideration of the constitutional constraints on the regulatory policies, it will be well to recapitulate the few guides that the foregoing discussion has made available to us. These are the following:

1. For a regulation to be sustained as a constitutional exercise of the police power, it must be shown to respond to a public purpose and to do so in a reasonable manner.

2. Additionally, the constitutional validity of the regulation depends on it not being unduly burdensome. Undue burden is an ambiguous phrase. If the regulation leads to physical occupation of the landowner's premises, or to his being denied all use of them, it will almost certainly be struck down. If it precludes uses that have traditionally been characterized as nuisances, it will almost certainly be upheld. The constitutional status of regulations falling short of either of these situations will be determined by tests relating the diminution in value suffered by property owners either to the value of their property unrestricted by the regulation, or to the damages suffered by others absent its protection.

First of all, then, constitutional regulations respond to a public purpose. The regulatory policies in which we are interested are those intended to abate, or mitigate the consequences of, the nine natural hazards with which the study is concerned. As such, they protect from loss one or more of three identifiable groups. These groups are (i) persons subject to the risks of hazards, (ii) persons suffering loss as a consequence of their being group (i) persons -- that is, for example, persons becoming subject to a flood or landslide because group (i) persons have been permitted to locate, or build an unsafe structure, in a risky area, and (iii) persons suffering financial loss as a result of their being group (i) and group (ii) persons -- that is, for example, taxpayers sharing the costs of damage compensation paid to group (i) and group (ii) persons. It would be difficult to imagine regulatory policies more responsive to a public purpose than these and any court would so find them.

The other findings required to constitutionally sustain police power regulation are of course reasonableness and no undue burden. Ideally, we would consider their features separately, but since the reported cases almost inevitably involve landowners suffering a greater than average burden, arguments about the reasonableness of a regulation (or the opposite) are often indistinguishable from arguments about the burden it imposes. Consider for example a municipal resolution prohibiting gravel mining. As applied to the owner of gravel-bearing land far removed from any competing uses and without any other economic use, would the issue before the court be reasonableness or undue burden?

"Reasonableness" and "no undue burden" tests clearly are going to be more difficult to establish for hazard management regulatory policies than "public purpose" tests. In order to evaluate them the courts need to know, in the words of the Supreme Court in Goldblatt v. Town of Hempstead [Judicial Decisions, 13], one of its few decisions in the area since Pennsylvania Coal:

> ". . . such things as the nature of the menace against which . . . (the regulation) will protect, the availability and effectiveness of other less drastic protection steps, and the loss which . . . (the property) will suffer from (its) imposition . . ."

Before going on to an analysis of the reasonableness of and burden imposed by the hazard management regulatory policies, it will be useful to expand on the above quotation with the factors considered important in the few reported cases involving policies intended to avoid or protect against natural hazards. We take up zoning policies first.

The zoning response to natural hazards has come before the courts far more than other policies [See Judicial Decisions, 7, 11, 23, 34, 35, 38, 41, 42, 43]. All the cases have involved the use of zoning to avoid the consequences of the hazard (uniformly riverine flooding and storm surge) by forbidding location of most uses in the higher risk areas. The zoning regulations under attack in these cases have had certain features in common. They precluded all but agricultural, recreational and park uses in the areas susceptible to flooding. Most of them also provided for a permit procedure under which owners could apply for variances.

The two facts that have most interested the courts in the zoning cases are the historical extent of flooding and the amount of the landowner's property subject to flood control zoning. In only two cases [Judicial Decisions, 11, 38] were both these facts adverse to constitutionality -- that is, the landowner's property fell completely within the restricted area and nothing was presented to show it to have been previously flooded. In both, the zoning was found to be unconstitutional as applied to the landowner. In another case the court redrew the boundaries of the flood control zone to conform with evidence on the extent of flooding in a previous storm [Judicial Decisions, 34]. In so doing the court was not impressed with the state's argument that predicted future development in the flood control zone should be considered in the redrawing; it held that the extent of flooding was to be determined solely on the basis of contemporaneous conditions. In all the remaining cases, the flood control zoning was upheld as drawn. It should, however, be pointed out that all but one of these cases involved landowners with property partially within and partially without the flood control zone. The exception involved land which had been flooded four times in 45 years, the most recent occurrence having swept away a model home built by the landowner as part of his intended subdivision [Judicial Decisions, 41].

Building and housing code responses to natural hazards have not been considered by the courts at all. Constitutional challenges to these codes have generally involved provisions addressed to ordinary health and safety, and the issue of their validity as applied to existing buildings. Almost uniformly these cases have sustained the code's constitutionality [See, for example, Judicial Decisions, 8, 33]. One of the few cases to invalidate a code on constitutional grounds is of interest here because of the court's dicta on the finding that would have been required to sustain it [Judicial Decisions, 4]. The case was brought by a manufactured home builder to enjoin application of local code roof-decking and corner-bracing methods. Those it proposed to employ, were sanctioned by various model building codes and were, in any event, the structural equivalents of the methods required by the locality. This being so, the court found the locality's requirements unreasonable and therefore constitutionally invalid. They could have been upheld, the court said, only upon "strong proof of a peculiar extraordinary hazard in the particular area, necessitating the higher standard in question."

As with building and housing codes, no case challenging the constitutionality of subdivision regulations as a response to natural hazards has come before the courts. Most of the attacks on subdivision regulation constitutionality have involved regulations requiring dedication of some portion of the land proposed to be developed for street or park purposes. In these cases, street dedication requirements have been uniformly sustained, while park requirements have met a mixed fate. Some courts have imposed the test that the recreational needs fulfilled by the required park be "specifically and uniquely" attributable to the proposed development [See for example, Judicial Decisions, 30]. Other courts have been more lenient [See, for example, Judicial Decisions, 1,2].

Regulations expanding the approvals traditionally required in the construction process for areas subject to natural hazards are very common. Only infrequently, however, has the constitutionality of these regulations been considered by the courts. One of the few cases to do so involved conditioning building permit issuance on a soil-stability study [Judicial Decisions, 19]. An affected owner sought to have the condition declared constitutionally invalid. He was able to show that the cost of such a study would exceed the value of his land (because he had brought suit before applying for a permit, and therefore without commissioning such a study, no evidence was presented on the value of his land were the recommended modifications carried out), and that a similar condition had not been imposed for land apparently subject to equal risk of slide. Nevertheless, the court sustained the condition's validity as the "minimum" necessary to assure the safety of future dwellings; it stressed that no alternative means for accomplishing this end had been shown.

It remains to consider constitutional challenges to mitigating natural hazards through disclosure requirements and compulsory insurance. The reported cases contain no such challenges. There are two explanations for this. One is the recency of such policies. Potential challenges have yet to make their way through the courts. The other is the wide acceptability of analogous policies in other areas. Disclosure requirements in the corporate securities field and compulsory insurance (financial responsibility laws for drivers and assigned risk pools for insurance companies) in automobile licensing, for example, have long been part of the national scene. Their constitutionality, never much in doubt, is now fully accepted. It would no doubt also be accepted in the natural hazards area.

In terms of hazard management policies which involve regulation of building practices and land uses, several comments are due concerning future judicial assessment of the constitutional attributes of such policies. First, in view of the above-quoted portion of the Supreme Court's decision in <u>Goldblatt</u> and of the cases which have been reviewed (particularly those involving zoning), we can say the extent of the hazard sought to be abated or mitigated will weigh heavily in any such assessment by the courts. Police power interference in other fields has sought to curtail or control behavior linked to contemporaneously-observable impacts. It has not always been possible to measure those impacts in money terms, but that they existed was undeniable. The behavior interfered with in the natural hazard area, however, is innocent in and of itself. It can only be linked to an observable impact through the intervention of a fortuitous event: the occurrence of both the hazard itself and its occurring with sufficient severity to lead to the impact. Constitutional challenges to police power intervention in the natural hazard area, therefore, will be most successful when it can be shown that the probability of a sufficiently-severe occurrence of the hazard is low. Flood plain zoning in an area subject to a severe flood only once every five hundred years is not likely to receive favorable judicial treatment -- as we have already seen in the reviewed flood zone cases. It is likely to be seen as a cheap way to acquire a park.

In addition to the extent of the hazard, the means chosen for its abatement or mitigation will also be carefully examined by the courts. They will seek assurance that, given the impact of the hazard absent abatement of mitigation, other equally effective but less drastic means are unavailable. Thus, for example, if it could be shown that expectable damage from the most severe earthquake could be completely mitigated by strengthening building structure, zoning of the affected area to preclude any building at all would be more vulnerable to constitutional challenge. An example of this kind of holding by the courts, in a non-hazard context, is the building code case reviewed above. The court there was willing to consider not only the equivalency of the builder's presumably less-costly alternative, but also its adequacy by the independent standards of model building codes.

Finally, we can predict that the losses imposed on particular property owners will be of major significance in any constitutional challenge to regulatory policies. Based on the flood zone cases, owners with property completely within the region in which activity is restricted will be in the best position to raise such challenges. The likelihood of their success in this has already been considered generally in the above discussion of Pennsylvania Coal. That discussion furnished us with the minimal guide that denial of all property uses increases the chances of property owner success. We know from the reviewed flood zone cases, that restriction of activities to the relatively unremunerative ones of agriculture, recreation and parks does not constitute-- at least when the hazard is a substantial threat -- a denial of all uses.

Another point made in the Pennsylvania Coal discussion reinforces the conclusion that restriction of activities in the hazard context will be upheld. We said there that an activity characterizable as a nuisance, one that involves physical invasions of neighboring premises, is generally held to be constitutionally susceptible to state regulation. Natural hazard situations present exactly this feature. Otherwise harmless activities, building a house, for example, can upon occurrence of the hazard trigger physical invasions of surrounding premises, subjecting them to avoidable harm.

Beyond the minimal denial of all uses test, the Pennsylvania Coal discussion instructed us to consider the loss suffered by property owners relative either to the value of their property or the damages suffered by others, in both cases absent regulation. Should the balance be too unfavorable to the property owners, a finding of constitutional invalidity would follow. What constitutes "too unfavorable," unfortunately, could not be specified with exactness. And neither could the content of the second standard, that of damages suffered by others. As noted above, in a situation (like that of a natural hazard) involving probable personal injury and death, the second standard does not tell us how to value those consequences on a basis commensurate with property damage.

Notwithstanding some uncertainty about the exact boundary, we can say that under either standard the courts will tolerate balances substantially unfavorable to a property owner. Unless the risk of the hazard is unsubstantial or the damage it would cause very slight, restrictions all but wiping out the property owner are very likely to be sustained. The likelihood should be further enhanced upon a showing of probable personal injury and death accompanying the hazard.

Fourteenth Amendment

We now consider briefly the constraints on hazard management regulatory policies posed by equal protection provisions like that of the Fourteenth Amendment to the Federal Constitution. The operative word in those provisions is, of course, "equal". The problem it poses in the regulatory area is that almost any regulation makes distinctions -- by geography, by function, by status, etc. -- and thereby, fails to treat everyone equally. Obviously, regulation would be impossible if simply making distinctions turned out to violate the Fourteenth Amendment. And so, of course, the courts have held. To make distinctions is not necessarily to treat unequally.

In interpreting the equal protection clause, the Supreme Court has developed a two-tier test for regulatory distinctions. When those distinctions are made in an area involving a "fundamental interest" (such as the right of free speech or the right to seek redress in the courts) or when they are made on the basis of "suspect classifications" (like skin color), the regulation is subjected to strict scrutiny. The state must show that the public purpose met by the regulation is compelling and that the distinctions it makes are necessary to further that purpose. When, on the other hand, neither a "fundamental interest" nor a "subject classification" is present, the regulatory distinction is only required to bear some reasonable relationship to a conceivable public purpose.

Under this two-tiered test, regulations restricting the use of property on the basis of geographical or existential distinctions, such as are likely to be part of hazard management regulatory policies, clearly fall within the area of more relaxed scrutiny. All that will be asked of them is that the boundary and existential lines drawn be reasonable in light of the public purpose.

Obviously, the tests applicable to hazard management regulatory policies share certain formal characteristics with the Fifth Amendment tests already considered above. There, however, we were concerned with the overall reasonableness of the regulations in light of their public purpose. Here, we are concerned with certain distinctions they are likely to make. Perhaps the most likely of these is distinction by location. We will consider this first.

In drawing the boundaries of restricted use zones or in requiring special preparation for sites of a certain character (for example, those having a slope of a certain degree), legislatures will be making, on the basis of available information, certain geographic distinctions. Inevitably, therefore, neighboring owners will be treated differently. As pointed out above, however, in and of itself, this is not a sufficient ground for a finding of constitutional invalidity. Legislatures enacting regulations must draw lines somewhere, and begin regulation sometime, and their determination in this respect will not be casually upset. Thus, classifying land within a certain distance from the ocean as sensitive and subjecting it to a more onerous construction permit process [Judicial Decisions, 39], or, because of the greater availability of information, singling out one of various suspect areas for the imposition of restriction [Judicial Decisions, 17], has been sustained. When, however, a regulation makes no sense -- when, for example, nature to the contrary, it distinguishes invidiously between owners on both sides of a stream, it is not likely to fare so well.

The other distinction likely to arise under hazards management regulatory policies is one treating existing uses differently than prospective ones. Suppose, for example, the regulations were to distinguish between structures constructed prior and subsequent to their becoming effective, subjecting the latter to more onerous restrictions. Once again the test is reasonable relation to a public purpose. The exact public purpose is of some importance here. In situations involving solely property interests, such as for example, a land development control zoning ordinance, distinctions bearing more lightly on existing uses relative to prospective ones are likely to be upheld. The greater expense which equal treatment would presumably impose on existing uses would constitute a sufficient basis for the distinction. If, however, the public purpose were mitigation of a substantial risk of substantial harm to the health and safety of persons, the courts would be likely to take another view. Unless existing uses were to constitute a lesser problem for health and safety than prospective ones, an unlikely state of affairs, the courts might refuse to permit enforcement of the regulation until it had been extended equally to both uses.

Consequences of Unconstitutionality

We want to consider here the consequences of the worst that can happen: the regulations have been successfully challenged as constitutionally defective. We begin with the consequences for the unsuccessful government.

What happens to the unsuccessful government depends, in the absence of specific provisions dealing with this eventuality, on the type of suit brought by the property owner. From the standpoint of the government, the most favorable type of suit would be one seeking a simple declaration that the regulations are constitutionally invalid. Upon conclusion of this action, all that would happen is that the regulation would not be enforceable. We will shortly take up the further problem of the identity of the persons against whom it is unenforceable.

Landowners in many states, however, are able to bring another type of suit that is of greater concern to the losing government. This is the action in inverse condemnation. Its theory is that the government's regulations have effectively taken the owner's property -- by depriving him of its beneficial use-- and that, as with any explicit making under the condemnation power, compensation is therefore owing. Upon conclusion of this type of suit, the owner would be entitled to the market value of his property, valued without consideration of the regulations. This, of course, would be a seriously adverse development from the standpoint of the government. Having set out simply to regulate the use of the owner's property, it would end up having to buy it.

In an attempt to avoid the dilemma posed by inverse condemnation suits -- that of either not regulating fully or having to expend scarce resources in condemnation awards -- regulatory acts sometimes limit challenges of their constitutionality to a simple declaration of valid or invalid. Provisions of this type have been judicially sanctioned [Judicial Decisions, 12]. They should be part of any regulatory act.

It remains to consider the persons against whom a regulatory act found constitutionally defective is unenforceable. While they could in certain extreme situations go further, courts in land regulation cases have generally limited the effect of their holding to the property owner or owners bringing suit. This is simple prudence in most instances. Regulations affect different owners differently. What is unconstitutionally burdensome to one may be beneficial to another.

Application to Existing Uses

Our discussion to this point has proceeded without specifying the existential status of the uses sought to be regulated. We have not, that is, generally distinguished between uses existing at the time regulations become effective and those coming into being afterwards. The only exception to this statement was a brief consideration of existential distinctions in connection with the discussion of equal protection. There it was concluded that under certain circumstances the constitutional validity of a regulation might be questioned if it distinguished between existing and prospective uses.

Here, in contrast to the equal protection issue, we want to know if regulations may constitutionally be made applicable to existing uses. We want, that is, to know if the state can not only preclude building in hazardous zones, but also require removal of buildings already there, if it can not only specify hazard-proof standards for new construction, but also require existing buildings to be brought up to those standards. Were the state to do so, it would not of course constitute the first retroactive extension of regulations of this type. Zoning for the traditional purpose of use segregation has long wrestled with non-conforming uses and measures designed to eliminate them, just as ordinary housing codes have been the source of campaigns to bring older structures "up to code." It will be useful to consider briefly how the constitutional constraints on elimination of non-conforming uses and code enforcement -- based on the same Fifth and Fourteenth Amendment type provisions already discussed -- have evolved.

The first zoning acts in the United States were prospective in application only. No attempt was made to eliminate existing uses not conforming to the acts because, among other reasons, it was thought this would enhance their chances of success in the expected constitutional challenge. With the passage of time this initial deference for tactical reasons has, according to Donald Hagman, been taken by some courts as based on sound constitutional grounds [Hagman, 1973, Section 155]. They have accordingly invalidated extensions of the original acts designed to eliminate or phase out non-conforming uses [See, for example, Judicial Decisions, 17]. This holding is, of course, not without its own logic. Most non-conforming uses after all are not serious interferences with the permitted uses of their neighborhood. A holding that public health, safety or welfare calls for their removal seems a bit harsh.

In contrast to the typical non-conforming use in a zoning situation, deviations from housing code standards are more likely to involve potential risks to public health and safety. Housing code provisions, particularly those singled out for enforcement in the reported cases, theoretically incorporate minimal standards of public health and safety. Courts have been willing, therefore, to uphold not only prospective but retrospective applications of these codes [See, for example, Judicial Decisions, 8, 33]. Some limit on this willingness is implied by their consideration, even in cases involving clear threats to safety (like the lack of protection against fire in a hotel), of evidence relating the cost of compliance to building value. It is clear, however, that the limit is more likely to be reached in a case involving little or no risk of personal injury or death.

Natural hazard regulatory policies are, of course, intended to mitigate damage, both to property and to persons, from natural hazards. They thus serve the purpose required by the courts in sustaining retrospective applications of ordinary housing codes. Accordingly, we can expect a favorable outcome in any constitutional challenge of applying retroactively those regulatory policies involving building strength. The expectation is more confident as risk of personal injury and death can be shown to be substantial, and as the costs of compliance are small relative to building value.

To the extent that they serve health and safety purpose, favorable outcomes also can be expected in constitutional challenges to retroactive application of those regulatory policies precluding use through zoning. This kind of regulation, however, presents an element of difficulty not usually encountered in the non-conforming use abatement cases. There some kind of substantially remunerative use, although probably not the most remunerative, will be permitted upon abatement. Here, however, the regulations may permit only minimally-remunerative uses (farming, recreation, parks, etc.) upon abatement and, in addition, would presumably impose on the property owner the costs of removing the offending use.

This additional factor may be expected to make the constitutionality of retrospective hazard zoning more problematic. However, in addition to its health and safety purpose, two other factors will go far to sustain such regulations. The first of these is the nuisance character of uses violative of hazard zoning. As we have already pointed out, otherwise harmless activities trigger invasions of neighboring premises upon occurrence of the hazard. The relevance of nuisance characterization here is that courts have been far more willing to countenance retrospective application of zoning in nuisance situations than otherwise [See, for example, Judicial Decisions, 29, 41].

The other factor which would facilitate the defense of hazard zoning is the presence of a grace period within which to remove the offending use. The provision of such periods, generally referred to as amortization, has enabled many courts to sustain retroactive application of ordinary zoning against constitutional challenges [See, for example, Judicial Decisions, 9,16]. In the hazard zoning context it will, a fortiorari, have this effect.

Upholding Constitutionality

Several factors may substantially affect the constitutionality of the regulatory policies on which we have targeted this discussion. We will consider the factual base of the regulatory policies, the preservation of administrative flexibility through a permit system,and the presence of a comprehensive plan for meeting hazards. The regulatory policy factual base will be taken up first.

As an initial matter it is important to stress the presumptive constitutional validity accorded by the courts to police power regulations. In most contexts, certainly in that of natural hazards, the courts presume regulations, to meet a public purpose, to be reasonable in light of that purpose and to impose no undue burden [See, for example, Judicial Decisions, 13]. As a practical matter, this means that to prevail, the affected property owner must establish the contrary of one of these presumptions. Unless he does this by a preponderance of the evidence, the state will carry the day. Evidence to this end introduced by the owner may of course be rejected or subjected to another interpretation as a result of evidence introduced by the state.

The existence of this validity presumption has made some legislative bodies careless. The facts which a truly conservative, or even prudent, legislative body would require to be verified have been skimped. In part this is a product of economics. Verification of the facts is a time-consuming and expensive process. It is easier to follow precedents, neglecting the local peculiarities that may have shaped them. Fortunately (or in some cases unfortunately) for the regulations, this legislative carelessness is more than matched by property owner laziness. The reported cases contain relatively few instances of well-prepared factual attacks on police power regulations.

When legislative bodies attempt to legislate with care, the facts requiring verification are myriad. This is particularly true in the case of natural hazards. Most important would be a risk distribution for hazard occurrences of different geographic extents and physical intensities together with estimates of the property damage and personal injury associated with each occurrence and of the costs of mitigating that damage and injury. Evidence bearing on these facts may be culled from a variety of sources, most generally from the history of past occurrences and from expert opinion.

Legislatures that, in fact, seek to verify the facts outlined in the previous paragraph and then go on to establish the extent and intensity of the hazard occurrence to be abated or mitigated and the regulations thought appropriate to that end will provide themselves with the maximum possible protection against constitutional challenge. Against some property owners this may of course not be sufficient. The degree of regulation required by the hazard occurrence to be abated or mitigated may be so great as to effectively deprive them of all ownership benefits. In these situations it may be better to proceed by condemnation rather than tolerate the uncertainties of owner action. In most situations, however, the outlined procedure will protect the state. A court may find the evidence relied upon by the legislature to be weak, or it may disagree with the factual and policy conclusions based thereon, but it will be extremely reluctant to substitute its own judgment for that of the legislature. It will be helped to this conclusion if the legislature in adopting regulations has given notice to all affected property owners and provided them with an opportunity to be heard. To then allow an owner the chance to argue again will strike most courts as unfair.

In some cases, of course, a legislature will not be able, or would find it wasteful, to verify all the facts required for some regulations. For example, the legislature may not find it economical to trace with exactitude the boundaries for permitted uses in the hazard zones, but rather to describe generally the characteristics of the areas in which various uses are permitted. In these cases, instead of substituting a guess for the missing information, another procedure is available, a procedure which makes the regulations less vulnerable to constitutional challenge. Given that the legislature can with reasonable specificity provide criteria for decision--that it can, to continue the above example, specify by elevation or by soil or slope characteristics, or in some other manner the areas in which specified uses will be permitted--it can delegate to a permit issuing body the task of making the impact of its criteria concrete. Such a procedure is obviously less time-consuming and costly than one in which the legislature makes all the required determinations. When those determinations would necessarily, or for reasons of economy, be based on unsatisfactory evidence, the procedure is also fairer (and accordingly provides some protection against constitutional attack). The requirement that the legislature provide reasonably specific criteria for decision is made, it should be noted, on the basis of constitutional principles. Delegations of authority are required to be made with reasonably clear guides for its exercise. The legislature may not delegate the whole authority to legislate.

The last factor affecting regulatory policy constitutionality to be considered here is the existence of a comprehensive plan for meeting hazards. In order to see the effect of this factor we will consider the situation of a property owner subject to the hazard mitigation ordinance of one of the typically numerous municipalities in a hazard zone. If the other municipalities of the zone had either not enacted mitigation ordinances or had enacted substantially less onerous ordinances, the chances of upsetting the ordinance to which the owner is subject would be far greater. It would be open to him to argue that the ordinance was park acquisition under the guise of hazard mitigation. A similar argument is possible when the challenged legislation, although enacted by an entity with jurisdiction over the entire hazard zone, does no more than impose direct constraints on owner use and disposition of property. Were the jurisdiction truly concerned with the hazard, the owner can argue, it would also have adopted affirmative measures--such as those leading to more complete abatement of the hazard or to an adequate warning system.

The vulnerability of regulatory policies to constitutional challenge, therefore, will be decreased in the presence of a comprehensive--both in the geographic area and the subject matter covered--hazard plan. This will ordinarily require activities by an appropriate regional entity. Municipal boundaries only fortuitously encompass entire hazard zones. No court, however, is likely to require the regional entity to possess police powers itself. It will be sufficient if local governments enacting regulatory policies are guided in their framing by a regional plan.

Identity of Regulator

In this section we take up some constraints, other than those posed by the Fifth and Fourteenth Amendments, on the adoption of regulatory policies. The constraints to be discussed uniformly relate to the identity of the regulating government, whether local, regional, state or federal. We will be looking at the differences in results and pitfalls which accompany the choice of regulator. We begin by considering the states as regulators.

State Supremacy

Under the Tenth Amendment to the Federal Constitution, the states are reserved all powers not granted to the federal government. One of these powers is that permitting them to regulate--subject to other provisions of the Federal Constitution and their own constitutions--the activities of persons and artificial entities subject to their jurisdiction. This power is commonly referred to as the police power.

Many matters over which the police power would confer authority to regulate are commonly left untouched by the states. Some of these are unfettered because it is thought better that they be left to the discretion of individuals. As to certain other matters, police power authority has been delegated, more or less without guides in its exercise, to local government units: cities, counties, special districts, etc. The usually unexplicated rationale for this delegation is the local nature of the matters. Since they principally affect the persons joined together as local governments, they can, both from the standpoint of efficiency and equity, be left to the discretion of those governments.

Finally, the states have, of course, exercised their police power authority over many matters. Sometimes these have seemed to coincide with authority granted to local governments. The controversies generated by these intended or unintended state preemptions, and their implications for natural hazard regulatory policies, will be briefly reviewed in the discussion that follows.

Delegation to Cities and Other Local Governments

There are two principal methods for delegating state police power authority to local government units. The most far-reaching permits local governments to draft and adopt charters for self-governance. This method, known as home rule, is sometimes amplified by an affirmative grant of power to legislate with respect to municipal affairs.

The other method of delegating is a grant of power over specific matters. For example, state legislation frequently empowers local governments to adopt zoning ordinances.

Both methods for delegating state police power have generated doctrines limiting the apparent grant of power. Specific grants, for example, have been limited by a doctrine, which has come to be known as Dillon's rule [Dillon, 1911]. This rule, as noted above, confines local units to just the expressed powers and to those additional powers necessary to give effect to the expressed powers. To this end, specific grants of power are interpreted strictly and any doubts are resolved against the local governments.

Home rule charters, in addition to being subjected to Dillon's rule, have also been limited by a judicial prejudice against novelty. In 1920, when zoning was just coming into use, for example, home rule was held not to authorize a local zoning ordinance [Judicial Decisions, 10]. The decision was based on the "unusual scope and far-reaching possibilities" of the ordinance.

A third limiting factor can be seen at work in recent judicial consideration of home rule and specific grants of power. This is the hesitation to approve legislation which has effects extending beyond the boundaries of the enacting jurisdiction [See, for example, Judicial Decisions 25, 44]. This hesitation is based on the frequently undesirable economically-uncompensated costs that are imposed on outsiders--and on the fact that these costs are imposed without the participation of the outsiders in the process leading to their approval. Some suburban zoning ordinances, for example, have been condemned because their lot size requirements effectively exclude relatively less well-off families residing elsewhere in the region of which the suburb is a part. The issue in such cases can be seen as one of intent interpretation: did the authorizers of home rule or the specific grant of power (either the legislature in the case of statutory legislation or the people in the case of constitutional provisions) intend it to be exercised in such a way as to have undesirable effects on persons external to the enacting jurisdiction, but internal to the authorizing one?

Well-drafted state legislation is the answer to the doctrines of limitation and the hesitations reviewed above. Dillon's rule is avoidable by making the grant of power in the subject under consideration comprehensive, and the novelty doctrine of the home rule cases is, of course, avoided by the mere existence of specific enabling legislation. Judicial hesitation to uphold local ordinances with spillover consequences is less easily handled. The best solution would be the incorporation in the enabling legislation of evidence indicating legislative consideration of the problem. In some cases this will be achieved by tying the validity of local ordinances to compliance with procedures providing all affected interests an opportunity to influence the result. In the area of hazard mitigation an example of this approach would be conditioning the validity of local government regulatory policies on their being consistent with guidelines established for an area co-extensive with that of the hazard in question. How those guidelines would come into being--that is, the nature of the regional body required to establish them--would also be specified in the legislation.

The imposition of state requirements designed to avoid spillovers from local government regulation raises an interesting consequence of home rule. Its intent, to give general purpose local governments a measure of autonomy in their local affairs, has been thought by some courts to call for constitutional invalidation of certain kinds of state requirements [See, for example, Judicial Decisions, 37]. To uphold them would, it is reasoned, interfere with the exercise of home rule powers. Such a holding is, of course, only possible in the states that confer home rule constitutionally. In those that confer it statutorily, the imposition of state requirements is merely the undoing or modification of what had come before, namely the award of home rule powers. Even in the constitutional home rule states, however, the basis for holding state requirements invalid is quite limited. For matters of governmental structure and organization--whether the municipality has a treasurer, or what council majority is required to override a mayoral veto, for example--there is clearly a substantial basis for such a holding. However, for matters affecting a more extensive constituency--minimum lot zoning or hazard mitigation regulations, for example--striking down state requirements because they conflict with local action under home rule is excessive. The conflict, after all, is a result of action taken locally but not having solely local consequences. Assuming the state requirements do no more than alter those consequences to accord with the needs of the state's wider constituency--which includes all those affected by the local action--they can be upheld without threatening home rule. The alternative to upholding them is an unrealistic segregation of "state" and "local" functions. Experience in the federal-state context has taught us the futility of such distinctions [See Grodzins, 1966].

Regional Authorities

We have already discussed above the desirability of regional authorities in the natural hazard area. There they were of interest as factors likely to enhance the constitutionality of natural hazard regulatory policies. Here we want to consider briefly a possible challenge to the creation of regional authorities, whether with the power to engage in regulation itself or just to draw up a plan that local governments will be required to follow in framing their regulations.

The basis of the challenge to regional authorities to be considered here is the one derived from the home rule grant of power already discussed above. As noted there, some courts have thought it necessary to invalidate state requirements designed to avoid spillovers from local government regulation in the name of preserving home rule. Obviously, a similar argument can be advanced against another means of avoiding spillovers--the creation of a regional authority.

One of the most important cases to pass on a challenge of this kind involved the Lake Tahoe Regional Planning Agency [Judicial Decisions, 29]. The challenge there, made directly by local governments of the area falling within the agency's jurisdiction, was rejected on the ground that the problems leading to the creation of the agency were regional and, therefore, required a regional solution. The home rule grant of power was not interfered with because it comprehended only local matters.

Federal Intervention

The last matter to be considered is that of the federal-state relationship. As already noted above, the Tenth Amendment to the Federal Constitution is the explicit source of state police power. By its terms, however, the amendment subjects the powers exercisable by the states, including the police power, to the powers granted to the federal government elsewhere in the Constitution. The most far-ranging of those granted powers is probably the power over interstate commerce. Under its terms, federal interference in state affairs has been extensive.

The source of the other major federal interference in state affairs has been an indirect one. Under the power to spend for the general welfare, the federal government has made grants to state and local governments for various purposes. Those grants frequently have been conditioned on compliance with ends the Federal government would not be able to attain directly. One of the more extreme such conditions is that which prohibited employees of state and local agencies receiving federal assistance from taking active part in political campaigns. The penalty for non-compliance was a deduction from the assistance of an amount equal to the offending employee's salary for two years. Under this condition, therefore, the federal government effectively regulated an almost purely local matter--the political activity of local employees. The Supreme Court, however, was unwilling to find it an unconstitutional interference with state sovereignty [Judicial Decisions, 26]. Since that case, the challenges to federal grant conditions have been rare. Thus, while the theoretical possibility of federal overreaching still exists, it is difficult to imagine an interference that Congress would countenance and the Supreme Court find invalid.

Socio-Political Constraints

However large may be the legal capacity of a governmental jurisdiction or entity to deal with a natural hazard impact, the willingness of governmental decision-makers to deal with these matters may be influenced by a variety of socio-political factors.

These factors have to do with the values, perceptions, motivations, priorities, and preferences of hazard-exposed populations, other involved parties, public opinion formers and leaders, political activitists, whole political constituencies, professionals and administrators, decision influencers within government, and--of course--the policy-makers themselves. Additionally, of course, the representational foci of community and political leaders, policy-influencing parties, and the policy-makers themselves may be expected to influence the outcome of the policy-making process.

The gross outline of the linkages between these many factors is depicted in Figure 1-1. As suggested there, the activators of the public policy system are the set of phenomena referred to as "public problems," which--under appropriate circumstances--may become the focus of "political demands" upon the policy system and, thereafter, may be escalated to the status of "public policy problems" and placed on the "public policy agenda" for action [Anderson, 1975].

The model, of course, denies the validity of "folk wisdom" concerning the American legislative process: i.e., that public policy springs full-blown from the wisdom, compassion, public problem-sensing, and problem-solving skills of legislators. Without denying that legislator-initiated and engineered public policy sometimes--perhaps, frequently--emerges from the system, the model tends to accept the perspectives of Anderson [1975], Davies [1975], Keefe and Ogul [1977].

As observed by the latter authors,

> . . . the fact that the legislature is empowered to make laws does not mean that it initiates the ideas for legislation. Indeed, for the infusion of ideas and the origination of most legislation, the legislature is dependent upon familiar 'outsiders'. . . . Neither the wide perception of a social problem by legislators nor their recognition of a group's particular claims for governmental action is certain to lead to legislation. The chances . . . increase when (1) influential pressure groups mobilize their members and seek a governmental solution; (2) the unorganized public becomes intensely concerned with the matter or, conversely, is indifferent to the special measures sought by a pressure group; (3) the parties and powerful legislators take up the cudgels; and (4) the formation of strong counter-pressures to defend the status quo fails to materialize.

Both a law professor and a state legislator, Davies [1975] asserts that the success of a legislative proposal depends on action by outsiders; actions which both result in the formulation of a specific policy proposal and which make it possible for legislators to support the proposal. Within the context of the Davies perspective, legislators are seen as functioning more as "judges" of proposal efficacy than as discoverers of public problems and as initiators of solutions to those problems. To legislative outsiders, according to Davies, falls the task of generating public and legislator interest in problems and problem solutions and the further function of creating a socio-political environment within which it becomes possible to design and enact public problem-focused public policies.

Even if the above perspectives of the American legislative process are overstated, it is clear that public policies do not emerge full-blown from the head of Zeus; that policy-compatible socio-political environments must be fashioned; and that much time must be devoted by policy-sponsoring legislators to the guiding of proposals through the legislative process. In respect to the latter, Clapp [1968] quotes a U.S. congressional leader as having stated, ". . . I don't believe there is any man in the House who can do a really effective legislative job on more than two bills in a year. If you do that, you have a full-time job." Commenting on the necessity for such activity, Keefe and Ogul [1977] observe that

> . . . the overriding strategy in the advancement of legislation, from introduction to final vote, is to fashion a bill that can attract and consolidate the necessary support, preferably with a minimum of concessions to opponents. The process of winning support calls for tapering demands from the optimal down to the acceptable--ranging from what is most desirable to what, if necessary, will do--. . .

Within the limits of these perspectives and the general model presented in Figure 1-1, it, therefore, is important to dispose of the following questions: (1) What factors influence the social definition of a phenomenon as being a public problem? (2) What factors influence whether or not public problems become the focus of constituency development and political demand-generating activities? (3) What factors influence the placement of any such problem on the public policy agenda? (4) What factors influence policy-maker ranking of items on the agenda and the nature of the action which is taken to dispose of agenda items?

The development of answers to these questions seems to be particularly important in respect to natural hazard management policies. As noted elsewhere in this report, natural hazards do not necessarily exert their adverse impacts on significant elements of the public on a continuous or near-continuous basis. Neither are such effects necessarily visible to all segments of the impacted parties, nor are the causes and solutions to these impacts necessarily clearly perceived. In respect to the former point, such catastrophic occurrences as earthquakes, great hurricanes and storm surges, and devastating tsunamis do not occur very often. To the potential problem-impacted parties they are "unexpected" and "unfortunate" occurrences which reap their damage on the impacted parties as a result of remote chance and bad luck. Even when visited by such a calamity, the impacted parties tend to shrink from the conclusion that the phenomenon may occur again in the future and, instead, seek to continue with their lives as before [Mileti, Drabek, and Hass, 1975].

Illustratively, the most devastating civil disaster in American history was the Galveston hurricane and storm surge of September 8, 1900. The tropical disturbance from which the storm evolved was first detected on September 1 and struck Galveston, full-force, on September 8 and then took another week to disappear over the Great Lakes. During the single night of its strike upon Galveston Island, hurricane winds and storm surge flooding claimed approximately 6,000 lives--or about 10% of the Galveston population--and left only a few undamaged structures standing upon the island [Halstead, 1900]. In the days following the strike of the hurricane upon the island, on-the-scene observers described the situation in words such as these:

> Fever is appearing among the survivors and the medical staff is unable to cope with it. What little water there is is polluted with disease germs, and the pestilence is spreading. Nothing can stop it but the arrival of doctors and supplies. Parents are warned to keep away from the dead wagons in which their children have been tumbled, and long-barreled rifles back up the warning. . . . The safety of the . . . living necessitates this course, for the hot sun is already breeding disease and pestilence from the hundreds of decaying bodies. The city is a vast carnal house. The dead wagons hurry from place to place, filling with the awful cargo, and then speed away to the docks, where the bodies are dumped into scows and towed out into the Gulf. The waters of the Gulf float the bodies for a few minutes, then swallow them up. There are no services, no prayers, no tears--just a small 'splash', 'splash', as the corpses are thrown to their last resting place. Then the funeral cortege of scows returns to the docks for another load.

One week after the storm passed through Galveston, the community's Mayor Jones reported that:

> We are broke, the majority of us. I hesitate to say how much it will take to put Galveston where her people can care for themselves . . . There is not a building but is damaged, not a house of those left standing but will have to be re-roofed, and few that will not need to be straightened on their foundations. . . . It is true Galveston is represented as being one of the wealthiest cities of the country. But our rich people had everything here and are crippled. The people of moderate means, who had homes and worked on salaries, are scarcely an exception, ruined. . . . The island in the sparsely settled parts seems to have been swept clean. [Halstead, 1900]

Two weeks after the storm strike, a report from Galveston indicated that

> . . . many families refuse to leave. Scores of persons are living in their wrecked homes here. Many of these houses are without floors and devoid of all sanitary provisions . . . The foul stench from the carcasses makes sleep almost impossible at night, and strangers who come here do not remain long on account of the terrible odor. The lime which was ordered a few days ago for disinfection purposes has not yet arrived. . . . The work of burning the decaying human bodies and other carcasses which are to be found under almost every pile of wreckage continues . . . The waters of the Gulf are giving up dead bodies constantly and the shore of the mainland and the beach of the island are strewn with them . . . There are only ten houses in a habitable condition south of High Island . . . [Halstead, 1900]

On September 18, 1900, a correspondent from a Chicago newspaper reported from Galveston that the city

> . . . has been struck three times with floods and hurricanes, but even this experience is not enough to convince the residents that it will ever happen again. Only a few more cautious have any idea of taking steps to prevent a repetition of the recent disaster. Asked if there will be anything done to make future floods impossible, they will quote the old saw: "Lightning never strikes in the same place twice." [Halstead, 1900]

A representative of the U.S. Coast and Geodetic Survey reported from the disaster scene that some of the damage from the storm surge was due, in part, to removal of sand dunes that originally had protected the eastern end of the low, flat island on which the city was located. As the city expanded, these dunes had been leveled off and, thus, there was no break against a violent wind or sea moving from the east. Much of the post-disaster discussion focused on providing for the construction of a sea wall to protect the city from future occurrences and on means for advancing the reconstruction of the entirety of the area.

Amid the scenes of the immediate post-disaster period, one of Galveston's best known citizens and merchants stood near the center of the devastation and said, ". . . We are going to straighten out everything. We are going to stay here and work it out." A day later, the local newspaper stated:

> Galveston must rise again. . . . The loss of life and property is appalling . . . but with resolute faces, the sentiment (is) . . . that out of the awful chaos of wrecked homes and wrecked business Galveston must rise again. The sentiment (is) . . . not that of bury the dead and give up the ship; but, rather, bury the dead, succor the needy, appeal for aid from a charitable world, and then start resolutely to work to mend the broken chains . . . Galveston shall rise again. . . . The blight and ruin which have destroyed Galveston are not beyond repair; we must not for a moment think Galveston is to be abandoned because of one disaster, however horrible that disaster has been. . . . We will bravely undertake the vast work of restoration and recuperation . . . [Halstead, 1900]

Today, Galveston has, of course, been fully rebuilt and has, apparently, nearly forgotten this disaster in her past. From end to end, the 35-mile long island, which rises only a few feet above sea level, is marked by subdivisions and commercial establishments that reach out nearly to the mean high tide line. The devastation of the sand dunes appears to have continued unabated throughout the 78 years that have passed since the hurricane and storm surge of 1900. Stronger buildings have been constructed than were in place in 1900 and most beach-lot residential structures have been elevated several feet above the ground level. The area is an attractive site for second home developments and for permanent residents. There is little evidence that would lead one to conclude that any of the island's current inhabitants seriously believe that another disaster could strike again. The attitude is typical of that which prevails among disaster-struck populations.

As near as one can tell, the "problems" that Galvestonians and others read into the great catastrophe of 1900 were phenomena that related to the availability of aid from outside sources during the post-disaster period, to the need for capital to rebuild a disaster-struck city, and to the need for engineered systems that might reduce life loss during the actual hours when hurricane winds and storm surge waters sweep through a hazard-prone area. The diversion of capital, manpower, and other resources from non-hazard-prone areas was apparently never viewed as, itself, a problem, nor was the building of a city in such a hazardous area so viewed. Thus, all of the efforts in the public policy arena in the post-disaster period were directed to these phenomena, rather than to the underlying causes of the disaster.

The response of Galveston to its disaster apparently is not unique. After hurricane Camille struck the Gulf coast in 1969, the slogan "We shall rise again" was emblazoned on automobile bumper stickers and store windows and was repeated over and over again in various mass media reports [Quarentelli and Dynes, 1973]. Apparently, the victims of community disasters usually see the post-disaster future in optimistic terms and do not seek to remove themselves from the hazard zone. With respect to victims in two tornado-impacted communities (Waco and San Angelo, Texas), for example, 52 to 74 percent thought their neighborhoods would be better in the long run [Quarentelli and Dynes, 1973]. Thus, a sense of optimism about the future and a willingness to rebuild seems to be characteristic of disaster victims.

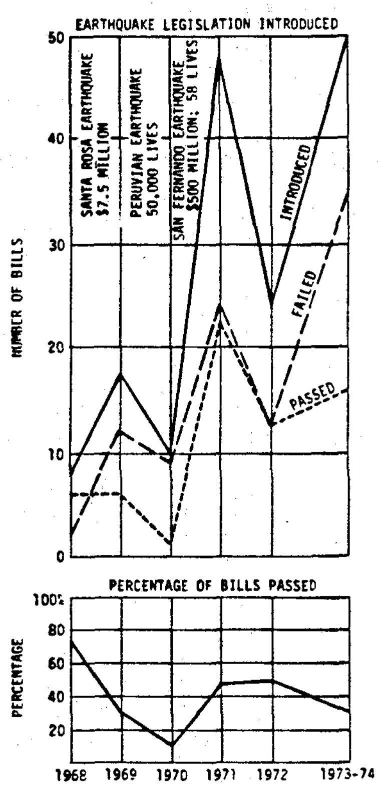
Within the context of the available evidence, therefore, it is appropriate to suggest that the socially-disvalued aspects of major hazard-induced events are those which impede efforts to rebuild and to get on with life as it was before. The notion that the area might better be left in an undeveloped or less-developed state does not seem to be typical, and the possible need to avoid the hazard in the future does not seem to motivate the impacted population to make a social commitment to future hazard-avoidance. Indeed, regarding physical hazards, avoidance motivations are strongest among those individuals who have not previously experienced the hazard [Golant and Burton, 1970]. Apparently, the acceptability of any risk--including those associated with exposure to natural hazards--is a function of such factors as the extent to which the risk is familiar, known, voluntary, controllable, catastrophic, and dreaded [Fischhoff, et al., 1976]. Even when a risk meets the last two criteria, those who actually have experienced the consequences of the risk-taking view the possibility of future exposures with less apprehension than those who have not and--in regard to natural hazards--

typically continue the pattern of prior risk-taking. However, the accuracy of hazard perception is influenced by whether or not one has "more", "recent", or "intense" experience with the specific hazard [Kates, 1971; Burton and Kates, 1964; Burton, et al., 1965; Roder, 1961; Saarinen, 1966]. Also, the preparedness level of individuals in communities seems to be higher among those with prior experience with the hazard [Kates, 1970; Russell, Areg, and Kates, 1970; Fritz, 1961; Burton and Kates, 1964]. Rates of adoption of natural hazard adjustments increase immediately after the extreme event [Saarinen, 1966; White, 1964] but decay thereafter. Hazards characterized by high frequency of impact are associated with the use of more adjustments [Kates, 1971], and low probability occurrences motivate fewer adjustments than do high probability occurrences [Burton, 1962]. Mileti, Drabek, and Haas (1975) summarize the available evidence as follows:

> . . . a general positive relation (exists) . . . between perception of hazard and adoption of adjustments . . . (It) is exceedingly rare for relevant adjustments to be adopted . . . insofar as they are designed to cope with highly unusual events such as damaging earthquakes. But immediately following particularly dramatic disasters there appear to be . . . attempts at improving adjustments to the hazard. . . . (A) large-scale disaster in one locale stimulates for a time the serious consideration of adoption of relevant adjustments in nearby similar hazard locales.

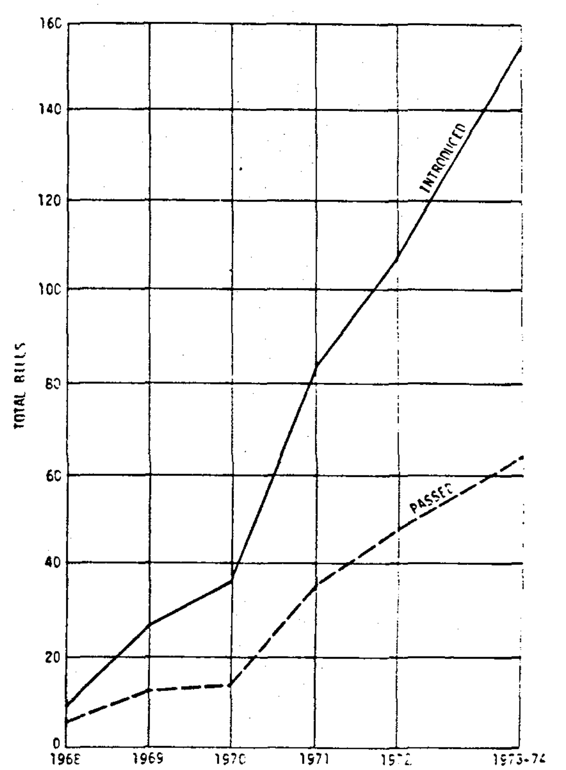
This tendency is clearly illustrated in the response to earthquakes in California. James Slosson, [1975], suggests that a strong "emotion reaction" factor stimulated natural hazard mitigation actions in California. In a study of legislation in that state for three years before and after the San Fernando earthquake of 1971, he notes that during 1969 and 1970 ten earthquake-related bills were introduced, but only one passed. Immediately after the 1971 earthquake 47 seismic bills were introduced, of which 23 passed; and the following year, 24 bills were introduced, 12 of which passed. During the next two years, 50 bills were introduced and 16 passed; of these, the majority were amendments or corrections to bills that were passed in 1971 and 1972. Slosson interprets the results of this analysis as a response by legislators in California to the emotional desires of a public affected by major catastrophes. Between disasters, there is generally a lack of legislative action; but, during the emotional period following a disaster, many hurriedly prepared and ill-conceived legislative bills are introduced, requiring corrective legislation. As indicated by the 1973-74 legislative results, he found that good, well-prepared, and technically sound legislation generally fails. This sequence strongly suggests, according to Slosson, that it is the responsibility of concerned people in science and technology to have technically sound legislation prepared prior to a disaster and then be willing to volunteer time and effort to assist the legislators when the emotional reaction runs high.

The earthquake-related legislation introduced into the California legislature between 1968 and 1974 is summarized in Figure 8-1. Figure 8-2 indicates the cumulative totals of the bills introduced and the bills passed during these years. In the seven years surveyed, approximately 160 bills were introduced, whereas slightly over 60 were adopted.



SOURCE: James E. Slosson; "Legislation Related to Earthquakes", California Geology, Feb. 75, p.37

Figure 8-1. State of California: Earthquake Legislation, 1968-74



SOURCE: James E. Slosson; "Legislation Related to Earthquakes", California Geology, Feb. 75, p.37

Figure 8-2. State of California: Cumulative Totals for Earthquake Legislation, 1968-74

In a study by Solomon and Okrent [1977] of the reaction by public bodies in Los Angeles to the 1971 San Fernando earthquake, the failure by the Los Angeles City Council to adopt stringent protective legislative measures in the case of a seismic event is documented. In Los Angeles, there are approximately 14,000 unreinforced masonry structures built prior to October 6, 1933. These structures are extremely vulnerable to destruction during an earthquake. However, after six years of debate regarding a seismic safety plan, the Los Angeles City Council was only able to approve a program of rehabilitation of these structures, rather than demolition or significant structural reinforcement. The Council did not explicitly define "rehabilitation" nor did they indicate what would be an acceptable level of safety. These events are discussed in greater detail in Figure 8-3. Thus, in Los Angeles, a city with recent (1971) major seismic activity, as well as in California as a whole, significant seismic policy legislation has not readily been adopted.

Consistent with the finding that parties inexperienced with natural disasters tend to exhibit more apprehension concerning such events is a further set of findings suggesting that "outsiders" tend to overestimate the recovery needs of disaster areas and to exaggerate the impact of a disaster on a community. Media exaggerations of disaster impacts apparently increase as a function of distance from the disaster site [Quarentelli and Dynes, 1973].

This situation undoubtedly contributes to the pervasive social tendency to overstate the impacts of hazards that produce death (rather than just injuries) and that take multiple (rather than single) lives and to a companion propensity to underestimate the risks from common, undramatic hazards that claim one person at a time [Slovic, Fischhoff, and Lichtenstein, 1976].

Thus, there is a general social or "outsider" tendency to overstate the impacts of hazardous natural events, to exaggerate the needs of those who are impacted by such events, and to understate the importance of less dramatic hazardous incidents and activities. Those who do not experience the disaster tend to deny that they, too, may be threatened by the hazard [Burton, Kates, and White, 1968] by denying its existence ("we don't have floods here; only high water"). Those

DATE	EVENT OR ORDINANCE
2/09/71	San Fernando Earthquake with magnitude 6.4, or with maximum modified Mercalli Intensity VII to IX in the San Fernando Valley and MM VII in central Los Angeles. The earthquake severely damaged the Veterans Hospital and the Olive View Hospital in the north San Fernando Valley. There was moderate damage in downtown Los Angeles, especially to older buildings with brick and masonry facings.
12/12/71	Geology Professor James Slosson warns California builders against forgetting the lesson of the 2/9/71 earthquake. He cites Los Angeles Ordinance forbidding building within 50 feet of the San Andreas Fault as being arbitrary and based on old, unreliable data.
5/20/75	Los Angeles City Council adopts May 20, 1975 Earthquake Safety Plan. The plan identified City's intention to eliminate hazards associated with older construction standards, (but did not impose specific requirements).
9/20/75	Los Angeles City Council adopts September 10, 1975 Seismic Safety Plan. The objectives of the plan included: • Encourage public awareness of earthquake hazards • Assure minimum design standards against earthquakes for critical structures such as dams and hospitals • Ensure City's emergency communications network after a major seismic disaster • Reduce risk of life and property loss as a result of an earthquake • Evaluate levels of risk with respect to earthquake damage • Determine the relative seismic risk in various parts of the City as a guide to new development • Minimize nonstructural damage from ground shaking • Guide in the determination of future land uses within zones of potentially higher seismic risk • Facilitate post disaster recovery • Assure the sound and rational reconstruction of Los Angeles following a major disaster The Seismic Safety Plan did not, of itself, impose any changed requirements.
3/12/76	Seismic Safety Committee analyzes possibility that 4,500 square mile crustal blister along San Andreas Fault may be premonition of impending major earthquake.
3/17/76	Briefing given to Governor Brown by the U.S. Geological Survey regarding this blister.
4/08/76	Los Angeles Times Editorial reports seismologists ability to forecast earthquakes as imminent. Comments that land swelling along San Andreas Fault may be precursor of extensive temblor, and that local government should therefore require 14,000 unreinforced-masonry buildings to be either strengthened or demolished.

SOURCE: Solomon, D.A. and D. Okrent. Seismic Building Codes for the City of Los Angeles, California. Brief Case Study. Rand Report #P-6018, November 1977.

Figure 8-3. Significant Events and Ordinances Following the Feb. 9, 1971 San Fernando Earthquake

DATE	EVENT OR ORDINANCE
4/15/76	The Los Angeles City Council fails to approve ordinance by the Conservation Bureau of the Department of Building and Safety, which, if approved, would have required the owners of unreinforced masonry buildings of 100 or more occupants and built prior to October 6, 1933, to either repair their buildings in accordance with the seismic code or demolish them.
8/28/76	The Los Angeles City Council approved changes in building codes policy which would require 14,000 old buildings to post public notices warning of risk of occupying unreinforced masonry buildings to improve structural standards. However, this policy has not yet been adopted and according to a City Councilperson, it is not expected to be.
10/25/76	The Los Angeles City Council's Building and Safety Committee recommends an ordinance requiring strengthening of all unreinforced masonry buildings in Los Angeles within ten years. They said that the Federal Government should be called on to provide loan and grant aid to prevent some of the major consequences of severe earthquake.
11/27/76	The Los Angeles City Council failed to act on proposed new ordinance that would apply current seismic safety standards to 14,000 earthquake-endangered buildings constructed prior to 1933.
11/29/76	Los Angeles Times Editorial claims that 75,000 to 100,000 persons regularly use the 14,000 buildings in question.
1/25/77	The Los Angeles City Council approves program of rehabilitation, rather than demolition, of 14,000 buildings which are made of unreinforced masonry and which would suffer major damage during an earthquake. The program also included a proposal of a two-year study to assess environmental impact, to identify buildings at risk, and to recommend those needed improvements to ensure safety. The Council did not explicitly define "rehabilitation" nor did they indicate what would be an acceptable level of safety.
1/78	According to a Los Angeles City Council member interviewed by the author, the Council is expected to approve, within about a year, a building code amendment for earthquake safety for existing buildings. These amendments are expected (by the Council member) to be "moderate revisions" of those building code amendments defeated by the City Council on April 15, 1976. The nature of these "moderate revisions" was not explicitly defined; however, it was suggested that some City Council members are reluctant to require very stringent safety codes because the costs of implementing such codes may be unacceptable to the building's owner.

SOURCE: Solomon, D.A. and D. Okrent. Seismic Building Codes for the City of Los Angeles, California. Brief Case Study. Rand Report #P-6018, November 1977.

Figure 8-3. Significant Events and Ordinances Following the Feb. 9, 1971 San Fernando Earthquake (continued) actually impacted by a hazardous event tend to deny that a similar event will recur ("lightning never strikes twice in the same place"), to seek a restoration of things as they were before the event. Both groups apparently prefer to assume that others will take action to prevent recurrences ("the government is taking care of it"). To the extent that either group is motivated to take action to prevent future occurrences, the motivation is highest in the immediate aftermath of a self-experienced or nearby disastrous occurrence.

From the point of view of policy-makers--whether dealing with natural hazards or with other socially significant phenomena--there is a distinct preference for adoption of "distributive" rather than "regulatory policies" [Mayhew, 1974; Vogler, 1977; Mann, 1975] and a propensity to evaluate proposals in terms of what they will do for their own constituencies and their own chances for reelection [Mayhew, 1974]. Proposals advanced by large constituencies command more attention than those advanced by small or virtually non-existent ones [Schattschneider, 1960; Greenwald, 1977; Dexter, 1969]. With respect to natural hazards--and other potential problems--advocates of public policies, therefore, must consider the need for a constituency to be associated with their proposals [Olson, 1971; Jones, 1977]. Further, of course, it is clear that members of a potential risk-exposed constituency must perceive the risk associated with a hazard exposure if they are, subsequently, to be willing to organize so as to support risk-reduction proposals [Cobb and Elder, 1972; Schattschneider, 1960].

Since almost none of the above evidence points to a very glowing picture concerning the readiness of groups and individuals to initiate and/or support economically optimal, "cost-internalized", and loss-avoiding natural hazard management policies, it was assumed that--even in high hazard areas--local communities probably had done little that was not required by the federal government in order to mitigate the risks associated with natural hazard exposure.

To test this hypothesis and to gain a better understanding of actual levels of natural hazard policy and attitudes toward that policy by local officials, a systematic survey of a selected sample of 200 counties, chosen from the 500 counties with the highest expected damage rate from natural hazards as determined in this study [See Chapter 4] was conducted. From the 102 responses to the questionnaire, the number of municipalities indicating experience with natural hazard provisions numbered about 40; thus, a meaningful statistical analysis of this experience would be difficult. Nevertheless, the responses indicate that local communities generally have not adopted natural hazard provisions. If a hazard is addressed, that hazard tends to be flood, often in response to the requirements for Natural Flood Insurance eligibility.

Figure 8-4 indicates the range in damage rate of the 500 counties with the highest

RANK	COUNTY	STATE
1	STODDARD	MO
20	DADE	FL
40	MISSISSIPPI	MO
60	CHOWAN	NC
80	PENDER	NC
100	MANATEE	FL
120	EAST BATON ROUGE	LA
140	DEAF SMITH	TX
160	BARNSTABLE	MA
180	MCDONALD	MO
200	REFUGIO	TX
220	DIXIE	FL
240	NEWPORT	RI
260	CHURCHILL	NV
280	HERNANDO	FL
300	MURRAY	OK
320	TAYLOR	IA
340	NUECES	TX
360	WICHITA	TX
380	SAN JACINTO	TX
400	SANGAMON	IL
430	CHARLESTON	SC
440	GUADALUPE	TX
460	SCHUYLER	MO
480	NOBLE	OK
500	GRADY	OK

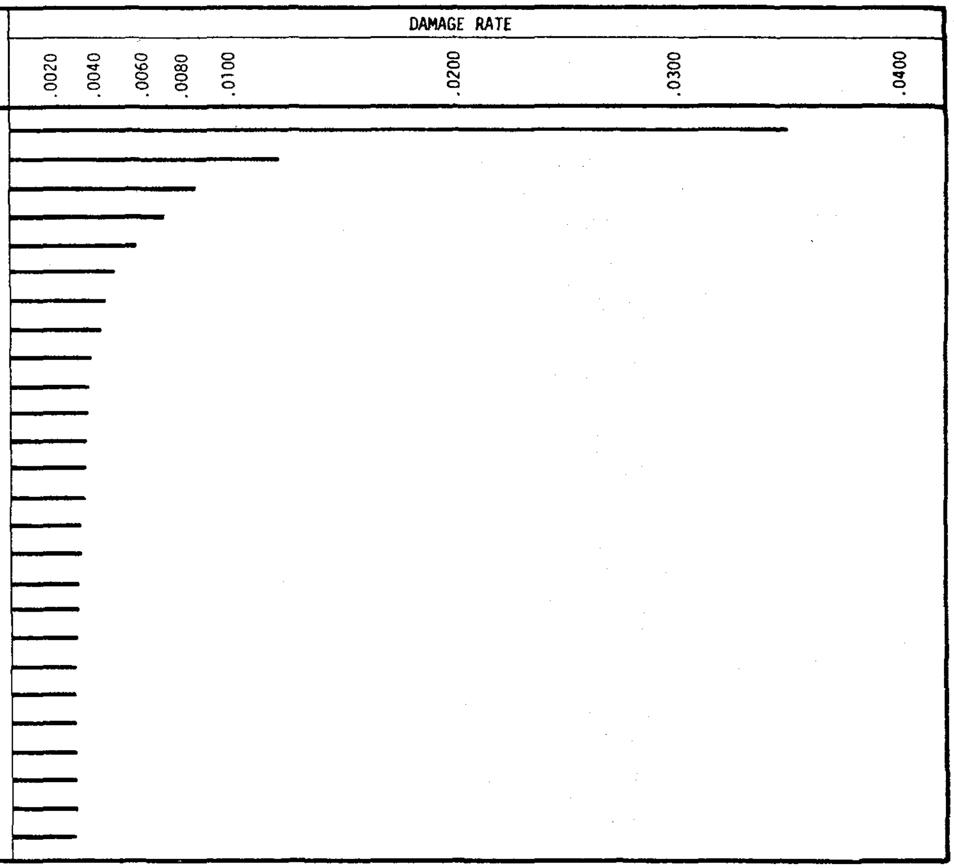


Figure 8-4. Range of Expected Damage Rates for the 500 Most Hazard-prone Counties, All Hazards Except Riverine Flooding

expected damage rate for all hazards other than riverine flooding; Table 8-1 provides greater detail for the 10 counties subject to the greatest potential damage rate from these hazards.

A primary concern in this survey was the perceptions of local officials of the natural hazards which they believe threaten their communities, compared to the

RANK	COUNTY	STATE	DAMAGE RATE (1)	INDEX (2)	VALUE AT RISK (MILLIONS $)	POPULATION (THOUSANDS)	MORTALITY RATE (x 10^{-3})
1	STODDARD	MO	.0351	18.00	161	25.7	.111
2	NEW MADRID	MO	.0345	17.68	147	23.4	.113
3	MONROE	FL	.0235	12.05	422	52.6	.168
4	VERMILION	LA	.0198	10.15	285	43.1	.0116
5	IBERIA	LA	.0186	9.53	380	57.4	.0121
6	JACKSON	MS	.0184	9.43	582	88.0	.0120
7	CAMERON	LA	.0174	8.92	54.2	8.19	.0106
8	NANTUCKET	MA	.0151	7.74	39.7	3.77	.0148
9	TERREBONNE	LA	.0147	7.53	619	76.0	.0102
10	COLLIER	FL	.0144	7.38	306	38.0	.0107

(1) Does not include riverine flooding
(2) County damage rate ÷ national average building damage rate for all hazards except riverine flooding in the year 1970

Table 8-1. The Ten United States Counties with the Highest Expected Damage Rate for All Hazards Except Riverine Flooding

calculated potential damage rates to their communities. Table 8-2 illustrates this comparison. If our predicted damage rate model reflects the actual level of hazard to these communities, this table shows that local officials tend to be unaware of the degree to which certain natural hazards threaten their communities.

HAZARD	RECOGNIZED BY JHW MODEL	RECOGNIZED BY JHW MODEL AND BY RESPONDENT	PER CENT OF MUNICIPALITIES RECOGNIZING HAZARDS ESTABLISHED IN THE JHW MODEL	RECOGNIZED BY RESPONDENT BUT NOT BY JHW MODEL
1 HURRICANE	34	31	(91%)	4
2 TORNADO	98	78	(80%)	0
3 SEVERE WIND	75	56	(75%)	10
4 STORM SURGE	31	27	(87%)	0
5 TSUNAMI	4	1	(25%)	3
6 EARTHQUAKE	66	14	(21%)	3
7 EXPANSIVE SOIL	101	18	(18%)	0
8 LANDSLIDE	100	4	(04%)	0

Table 8-2. Recognition of the Threat of Natural Hazards by Local Officials, in Comparison to the JHW Risk Model (excluding riverine flood)

Whereas the responding local officials recognized the hurricane hazard to the community in 91% of the communities where this hazard was recognized in our damage rate model, and 87% for storm surge, the level of recognition of most other hazards was substantially lower. Our model recognized the landslide hazard in nearly every location, although only 4% of the respondents recognized this hazard in their comments. In this case, we suspect that our model may have been insufficiently precise, geographically, to allow a determination of the landslide hazard for each individual community. Yet even in the hazards with wider impact areas, such as severe wind or earthquake, local officials seem to be less aware of the threat of natural hazard than our model would indicate justified. In particular, only 21% of the responding local officials in communities subject to earthquakes recognized this hazard in responding to our questionnaire. A tentative conclusion from this inquiry is that local communities are not aware of the threat from natural hazards which they face; therefore, they have not adopted mitigation policies.

Building codes are important in determining the type and level of mitigation policy standardized among communities; 28% of our respondents have adopted the Uniform Building Code and 23% have adopted the Southern Building Code (in addition, certain state codes such as North Carolina's are modifications of this code). Eight percent of our respondents indicated no building code in effect within their jurisdiction. However, fewer than half the respondents administer building codes that include specific natural hazard provisions, the most frequent of which is for flood. Other addressed hazards include hurricane, storm surge, wind, earthquake, landslide, and expansive soil. We asked local officials what the effect of natural hazard building code provisions has been on standard accepted building practices. Half of the respondents said that code provisions have no effect on building practices, and about one-third said that the provisions either hinder standard building practices or render them more expensive. It should be noted, however, that the low level of experience with natural hazard building code provisions suggests that the actual conclusion from this question is that we are still uncertain about what the effects of natural hazard building code provisions are on standard building practices. We suggest that experimental programs be undertaken to understand this effect in specific applications.

When queried regarding the effectiveness of current building code regulations in providing protection from major natural hazards, the few local officials with experience in this realm seemed to believe that the current building regulations offer some protection from natural hazards; approximately 75% of respondents noted that building regulations offer at least a medium degree of protection.

About 80% of the respondents' municipalities have adopted a general plan, but only about 66% of that group include specific language addressing natural hazards. Very few respondents indicated that their general plans address hazards other than flood, although soils, seismicity, wind, tsunami, and slope are included in at least one general plan from municipalities surveyed. Fewer of the respondents' zoning ordinances (38%) address natural hazards; in each case the hazard is flood, plus a handful of additional hazard treatments. About half of the respondents' subdivision regulations address the flood hazard, although others are being brought into conformance with National Flood Insurance regulations. Of those respondents indicating that their comprehensive plan, zoning regulations, or subdivision regulations contain no special natural hazard provisions, nearly two-thirds also indicated that the level of hazard in their community does not warrant special consideration in these documents. This perception would conflict with the estimated damage rate for these counties established in the present study.

If natural hazards are to be addressed in local level planning, one approach to understanding the nature and extent of the hazard and the effects of mitigations is to prepare a natural hazard impact assessment, similar to existing environmental or social impact assessments. We, therefore, asked local officials about their experience with impact assessments and asked them to project the usefulness to their communities of a similarly-conceived natural hazard impact assessment. It appears that more local officials have had experience with environmental impact assessments than with social impact assessments, and about half of the respondents indicated that these impact assessments have made a contribution to urban planning capabilities.

In responses assessing the effects of impact assessments themselves, it was frequently expressed that the environmental impact assessment thwarts attempts to look at the long range effects and consider the full picture of impacts and mitigating measures. At the same time, according to local officials, the procedure also adds to the data base and allows public involvement and understanding of the decision-making processes. Only a few respondents noted the positive effects of environmental impact assessment output measures, such as the actual alleviation of problems while they are still manageable. A primary concern over environmental impact assessment practice was the time involved in the review process and the strict regulations regarding the entire procedure. It was frequently expressed that a major drawback of the procedure is that it can delay construction and, therefore, increase costs.

These comments were generally directed not at the theory of environmental impact assessment but, rather, at its application. The more theoretical or intangible the assessment, the less useful it is, according to some officials, because it becomes more difficult to apply. Some officials also expressed the belief that their communities were already sufficiently familiar with the problems, rendering a full environmental impact assessment unnecessary.

Similar comments were expressed regarding social impact assessments, although fewer officials have had experience with them; the most frequent response was that such an assessment is unnecessary in the small community.

When it was suggested in the questionnaire that a social and environmental impact procedure be adapted for a natural hazard impact procedure, the response was generally negative. Three concerns were noted in particular: first, the hazard assessment should be included in the environmental impact assessment or other regulations rather than established as a separate process; second, several communities already impose requirements which they believe are sufficient to negate the effects of natural hazards; and, third, there was concern that the procedure would further complicate construction procedures. There was also concern about the standardization of impact assessments and their insensitivity to local conditions.

We also asked local officials who should be responsible for various phases of a natural hazard policy. Four suggested stages of involvement were policy setting, program planning, financing, and implementation. Their responses, shown graphically in Figure 8-5, indicate that they believe the appropriate level of involvement for all phases of natural hazard policy, except finance, is local government. Such policy should be established at the local level, and programs should be

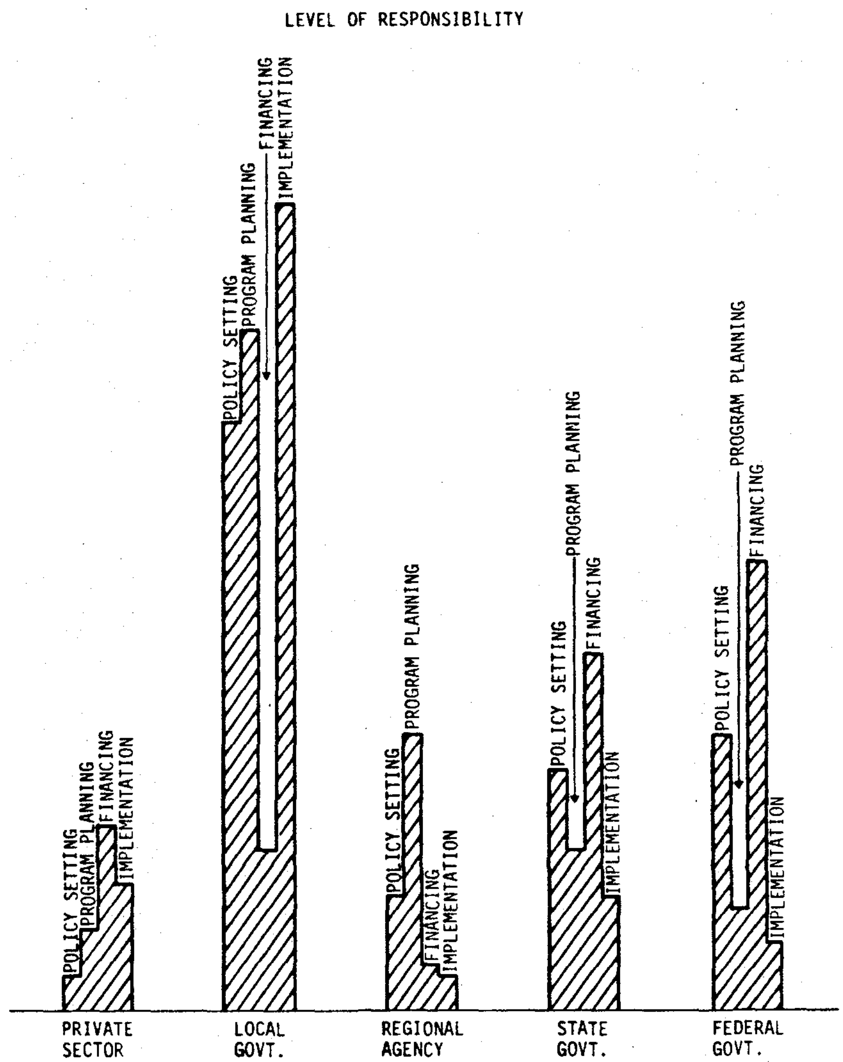


Figure 8-5. Comparative Levels of Appropriate Responsibility for Natural Hazard Policy - According to Local Officials in Hazard-prone Areas

planned locally, but the federal government is the appropriate financing body. These funds would be provided for local governments, which could then implement the policy. The most frequent response by local officials in this survey was that implementation should be carried out at the local level.

The conclusion from this survey, with respect to the perceived role and structure of natural hazard policy planning, is that local officials tend to believe that the most appropriate level for such planning is that of the local government; and comprehensive policy guidelines, such as those for a natural hazard impact statement, are not of great assistance at the local level. There is a reluctance to accept more requirements and guidelines for natural hazard planning established by higher levels of government; but, if such policies are established, local officials believe they should have an important role in the planning and implementation of natural hazard policy.

However, in spite of the limited experience of local governments and in spite of limited involvement of non-flood hazards by state government, there has been concern expressed by numerous agencies and organizations to establish more fully a comprehensive natural hazard mitigation policy.

The findings of this survey apparently are consistent with a larger but concurrent study conducted by James D. Wright, Sonia R. Wright, and Peter H. Rossi.* This survey involved interviews with about 2,300 politically-influential individuals in a sample of 20 hazard-prone states and 100 hazard-prone local communities. The complete results of this survey have not been formally published as yet, but they apparently suggest that natural hazards are not viewed as a very serious or high priority policy subject by local policy-makers and political influentials; that, to the extent a need for risk mitigation is accepted, preference is expressed for "distributive", rather than "regulatory", policies [Wright, Wright, and Rossi, 1978].

Value Constraints

Underlying the legal dicta and the personal, group, political, and policy-maker preferences which constrain natural hazards policy making are the value propositions and systems to which individuals and groups within our society are committed. A value proposition, of course, is both normative and prescriptive and defines an end that ought to be achieved or a course of action that ought to be followed. Although the correctness of value commitments cannot be determined through empirical methods, the consequences associated with the operationalization

*This study is being conducted under NSF Grant No. ENV 76-15441 awarded to the University of Massachusetts. County level loss data developed under the early phase of this study were used by the University of Massachusetts study team for assistance in selection of the hazard-prone states and communities.

of values may be examined. The holders of values may, of course, be committed to more than one value proposition or set of such propositions; and these commitments may exhibit some hierarchical or preferential ordering.

Great risk is incurred by anyone who presumes to assess the prevailing value commitments of a society. Values held by any one individual may be in conflict with those held by another and, of course, there is a lot of difference between groups in terms of their ascendant value commitments.

As the term is utilized in this study, an issue is a question so framed that it may be answered in either the affirmative or the negative and is, further, a question to which different parties will respond differently. Issues of fact are those which are capable of empirical resolution and deal with what is or what will be. On the other hand, issues of value are not subject to empirical resolution and can only be examined in terms of the predictable consequences that may result from their operationalization.

Numerous issues of value are associated with natural hazards management policy making.

In terms of prevailing value commitments, which are so universal that they may be viewed as constituting the constraining "givens" within which natural hazard management policy making will most likely be conducted, are the following:

(1) Special protection should be given to the young, the disabled, and the infirm, who are unable to care for themselves in the event of a hazardous natural occurrence.

This value proposition underlies such enactments as the California Field Act, which requires that schools and hospitals--both old and new--meet earthquake-resistant standards of a high order. Throughout our history, there seems to have been little social or political conflict surrounding the operationalization of this proposition.

(2) Individuals, groups, and governmental entities should so guide their decision-making and behavior as to avoid the infliction of serious damage and injury upon

other parties--unless some overwhelming public purpose requires such a course of action.

In its oldest form, this proposition is, of course, imbedded in the tort liability dicta we have inherited from the English common law. Even without any statutory prohibition against such conduct, one who willfully and knowingly engages in a course of activity that will cause injury to others invites a legal action by the injured parties that will be viewed with sympathy by our courts. One of the oldest expressions of this proposition is contained in the Code of Hammurabi, which was etched on the cliffs of ancient Babylon. In modern language, the code decreed that, if a builder was so careless as to construct a house whose walls collapsed and killed the son of the occupant, then the builder must--himself--sacrifice the life of his own son.

If anything, our social commitment to this proposition has grown stronger--rather than weaker--in recent decades. Thus, the 19th century slogan, "Let the buyer beware", has now essentially given way to the slogan, "Let the seller beware!" Product liability decisions made by the courts and product liability statutes enacted by legislative bodies throughout the country provide vivid evidence of this shift in social commitment.

Its implications for builders, developers, and governmental units, in respect to natural hazards management, may be larger than the literature now reveals. Thus, there may be real question as to the liability of a local government entity which--knowing that development within a hazard zone will result in future harm and/or dollar loss to those who occupy the developed area--nonetheless permits such development to take place. Similarly, a builder or developer who knowingly constructs dwelling units within such a hazardous zone and then withholds information from potential purchasers concerning those hazards may also well be inviting future tort liability actions.

(3) Opportunities for personal choice and decision-making should be preserved, and governments should intervene in such processes only when required by some ascendant public purpose.

Pervading our society is a strong and long-lasting social commitment to pluralism, to the right of individuals to "do their own thing", as long as that "thing" does not do harm to others. Although specific applications of this proposition sometimes provoke social controversy--as in the case of "crimes" involving acts between consenting adults--there is a general social willingness to gauge the efficacy of proposed policies against this standard. Thus, however hazardous to its participants, we are reluctant to deny individuals the opportunity to jump out of airplanes with parachutes strapped to their backs unless such individuals choose to do so over populated areas where such activities may result in injury to innocent non-risk takers on the ground below.

(4) The right of individuals to hold and use property is to be respected by their fellow citizens and enforced by government.

Social commitment to this proposition predates the founding of this republic, is very much a part of the struggle to separate the state from the church, was deeply imbedded in the dogma associated with the protestant revolution, and is, of course, one of the cornerstones of modern capitalistic and democratic societies. When conjoined with a prevailing social commitment to the view that individuals have a right to engage in activities that do not cause injury to others, this value provides a major constraint to the governmental execution of policies that might otherwise prevent future injury and death arising from exposure to natural hazards.

(5) Society should protect the rights of individual states and local communities to adopt rules and regulations which are considered in the best interests of their publics.

The constitutional tradition of the United States has been to leave as much decision-making power as possible with the individual states. Thus, there has been a consistent value commitment to decision-making based upon grass roots politics and pluralistic democracy. Natural hazard emergency preparedness and mitigation practices have therefore traditionally been the responsibility of individual states, with county and local governments performing the actual work.

When the Federal Government attempts to exercise its authority to engage in direct regulatory activity in this field or to establish action-forcing conditions upon the availability of federal benefits, loud complaints are voiced by local and state governments. The complaining states or local communities view these acts as a usurpation of or interference with their traditional rights and powers. This value therefore provides a major constraint to efforts to redefine the role of the federal government in respect to the management of natural hazard exposures.

Value Issues

Although other value commitments of our society might be listed above, this brief recitation underscores some of the major value constraints within which natural hazards policy making will take place. Also of great potential influence on such policy making are the following value issues, which, predictably, will comprise the focus of local, state, and national debates concerning natural hazards and the policies framed to deal with exposures to those hazards:

(1) Shall the death or injury of an individual exposed to a catastrophic event be given a higher value than the death or injury of an individual exposed to a non-catastrophic occurrence?

It seems undeniable that the American policy-making system responds more acutely and vigorously to catastrophic occurrences than it does to the less visible, less publicized occurrences that inflict injury or death upon many more persons, but in events that produce these consequences on only one or a few persons at a time. If our ascendant value commitments are to prevent the greatest number of premature deaths and unnecessary injuries per million dollars of available resources, then catastrophic occurrences would receive far less policy attention than is now the case. Whether our social and policy reaction to catastrophic and non-catastrophic events is due to our ignorance, to our misperceptions of reality, or to some underlying set of values that give greater weight to catastrophic than to non-catastrophic occurrences cannot be answered by these researchers at this time. Instead, the value issue can only be identified.

(2) Shall local governments be permitted to take action that is consistent with the interests of their current constituencies but antagonistic to the interests of their "Extended" and probable future constituencies?

This issue is one that assumes that the failure to decide or the failure to act may, itself, be viewed as a decision or action. The question, also, takes into account the phenomenon of the "shifting constituency" and the further pheonomenon of the "extended constituency". By the former term we mean, simply, that the constituency of any geographically-constrained jurisdiction of government may change drastically with the passage of time. At one point in time, the majority of the electors within such a jurisdiction may be owners of large plots of land devoted to the growing of citrus crops; but, only a few years later, the majority may be residents of single-family homes built upon the sites once devoted to the growing of orange and lemon trees. In a "representative" system of government, it is easy to suggest that elected policy makers must be responsive to the demands of those who have elected them and who constitute their contemporary constituency. But what about the constituents who have, at any point in time, yet to arrive on the scene? Similarly, actions taken by a local elected board in response to the clear interests and demands of citizens within the area may do damage to others beyond the jurisdictional boundary lines of that unit of government. Illustrative is the mix of actions that might be taken by a local unit to protect its citizens from the hazards posed by riverine flooding. The actions selected might well result in the mitigation of the local community risk but might increase stream flow within the floodways of downstream areas and, therefore, exacerbate the risk faced by members of the community's "extended constituency". As posed, therefore, this value issue is one that pervades discussions of federalism and of intergovernmental relations.

(3) Should voluntary risk taking that has a low probability of causing injury to others be prevented by the actions of local, state, and federal governmental entities?

This issue is one that presents markedly different implications, depending on the level of government to which it is addressed. Consistent with the prevailing U.S. social commitment to the notion of "pluralism", our segmented system of federal government, in theory, provides numerous opportunities for individuals with common interests and value commitments to come together in communities of their own choice. Some communities may opt for one style of life and one level of risk-taking, while others may reject such an orientation. When higher levels of government choose to act in certain areas, an inevitable consequence of such action is to push our system toward homogeneity and, therefore, away from pluralism. The point is important whenever the question of voluntary risk-taking is considered. Without denying that some risk-taking is almost purely "suicidal" in its root impulse and apparent consequences, it must also be remembered that there is much voluntary risk-taking that is associated with the receipt of compensating benefits. Thus, it would be folly to suggest that recreational parachutists are simply suicidal in impulse. Clearly, there is compensation to such individuals in terms of the sheer joy they derive from their hazardous sport. Similarly, the retired individual who builds his or her home on a beautiful, outcropping cliff above the blue waters of the Pacific may derive enormous joy from the taste of the sea and the excitement of the panorama, while at the same time be running the risk of losing his property and life through a slippage of the land into the sea below. A Midwestern couple that flees the hardships of the northern winters for the balmy climes of the Gulf Coast may be running the risk of death from storm surge but be experiencing the rewards of a more salubrious climate and the joys of walks on the beach. If the risk is voluntary, which, if any, unit of government is the better to deal with constraints upon that risk-taking?

(4) Shall government policy making in respect to natural hazards seek to serve "optimizing" (effective long term) or "satisfying " (short term partial solutions) goals?

(5) Should one type of natural hazard (i.e., earthquakes) be given priority over a more comprehensive approach to natural hazard mitigation?

(6) Should conventional criteria of cost effectiveness or cost feasible analysis be the principal basis for natural hazard policy selection?

(7) If disaster assistance is to continue, should disaster assistance be given to "individual" victims who have suffered natural disaster losses on the same basis

as now provided to whole communities which have suffered equivalent per capita losses? Where does equity lie in the current policy?

(8) Once made aware of the risks from natural hazards, should the individual citizen be required to internalize any losses incurred as a result of a natural event?

(9) Should local and state legislative bodies act as the "consciences" for their communities and select a policy risk level based upon informed analysis and testimony, as the basis for the adoption of natural hazard mitigation rules and regulations?

(10) Should natural hazard exposures be considered a national problem and thus subject to regulation by the federal government?

(11) Should the citizens of states who experience low damage rates, by virtue of the state's geography or management practices, be responsible through a federal taxing mechanism for the poor or improper land use and building code policies of another state?

(12) Should states and local governments bear primary responsibility for the mitigation of natural hazards and for dealing with the aftermath of a natural disaster?

Administrative Constraints

Whatever direction may be taken in respect to natural hazards management policy-making, the objective outputs of the policy-making process will also be influenced by constraints having to do with the characteristics, configurations, internal quality, authority, and resource availabilities of individual jurisdictions of government and of their organizational components. Thus, administrative constraints relate both to institutions and organizations and to the quality and quantity of the human and other resources that comprise their elemental building blocks.

In respect to natural hazards management, the organizations of principal interest will be those concerned with land-use planning and zoning, development and enforcement of subdivision and building regulations, hazard zone mapping, and policy analysis. Although there have been no major recent studies that have focused on the development of quantitative descriptors of the excellence and capacities of these institutions and organizations in the several levels of U.S. government, three studies have been made of this general subject within the past decade: the report of the Municipal Manpower Commission [1965], the research reports underpinning the activities of the National Commission on Urban Problems [1968], and the study conducted by Field and Rivkin [1975]. Of these, the latter two seem particularly relevant to this report.

In 1968, the staff of the National Commission on Urban Problems conducted a survey of a stratified sample of the nation's 17,993 local governments. The sample consisted of 3,104 of these governments, of which 81.7% responded to the survey The principal findings of the survey by the commission's staff were as follows: (1) Land use planning and building quality regulatory activities are widespread, directly affecting a high proportion of the nation's population and involving many thousands of local governments. (2) Most of the regulating governments are relatively small--apparently too small in most instances to engage any full-time employees for such work. This, of course, is a reflection of the prevailing atomized pattern of local government under which, for example, one-third of all the incorporated municipalities in metropolitan areas have less than 2,500 inhabitants and one-half are less than one square mile in area. (3) Even among the regulating governments that do have full-time employees for such work, pay rates are generally low, and only the largest governments have top-ranking jobs paying enough to attract and hold well-trained professional or technical people. (4) Local expenditure for these planning and regulatory activities is not insignificant--some $300 million annually. However, this sum is far less than one percent of all urban government expenditure and is even more strikingly dwarfed by the property values that are affected by such activities--more than $1,000 billion worth of urban real estate and over $50 billion annually of new construction. (5) Similarly, local government employees engaged in these activities number only 33,000 (full-time equivalent) persons, compared with some 3 million persons employed in the construction activities affected by their work. (6) Control of land use through local zoning ordinances and subdivision regulation is widespread and expanding. Of all zoning ordinances, a large proportion originated since 1950, and many have been considerably revised in recent years. Also, most zoning governments have reportedly prepared "master plans" of prospective land use. (7) Zoning governments deal with large numbers of requests for rezoning and "zoning variances" and, on the average, reject less than one-fourth of such requests. (8) Nearly all municipalities in metropolitan areas and a majority elsewhere have a local building code, but a considerable fraction of these codes has not been materially changed in recent years. (9) Of the cities and towns of 5,000-plus that have building codes, about two-thirds report that their local provisions are based upon a national or regional "model" code. However, only about one-fourth of these have recently adopted at least 90% of the updating changes recommended by the model code organizations. (10) There is great diversity in local code regulation of particular residential building practices. The survey asked about 14 specific building practices, including 13 approved by all applicable "model" codes, and one practice accepted by some, but not all, the "model" codes. Of these 14 practices, one is prohibited by over half the municipalities of 5,000-plus that have building codes, four others are prohibited by more than one-third, three by about one-fourth, and each of the remaining surveyed practices is rejected by some of these governments. Similar proportions of rejection appear for the municipalities whose local codes are reportedly based upon some national or regional "model" code.

The commission also examined procedures for enforcement of zoning and building laws and the processes for appeal from local findings. In respect to this subject, the commission commented as follows:

> The construction industry and related interest groups are extremely influential in the operation of appeal procedures. Representatives of the industry frequently are requested to recommend individuals for appointment to appeal boards, and codes and ordinances frequently require that members of appeal boards be architects, engineers, and contractors. Such practices would not appear to provide adequate protection to the public.

In the Field and Rivkin study, the authors comment:

> Most cities offer a salary and budget that failed to attract good people into code-enforcement jobs. According to 1970 data, in only the largest cities do salary ranges for building officials provide monetary incentives for efficiency and fairness in code enforcement. The potential for salary growth is limited. In most cities surveyed, there is a narrow range between beginning and maximum salaries. For all cities, $7,490 is the median for starting salaries and $9,600 for maximum salaries. Only in cities with populations of more than 500,000 did salary schedules offer much chance of job advancement. The overall median salary for chief building officials in 1970 was only $10,586, surely no incentive for aggressive leadership. . . . Building department budgets are generally too small to support adequate in-house training programs or to undertake ongoing code revision . . . To date the federal government has committed few of its resources to improving enforcement.

The authors of this same study also observed that one chief building official in seven is over 60, and over half of all chiefs are past 50.

> Limited budget, limited salaries, and limited prestige add up to uninviting job opportunities for bright young professionals eager to do a job. Even those willing to accept the unattractive entry inducements are handcuffed by lack of funds for professional training, comprehensive code revisions, and evaluations of their own enforcement activities.

The authors of the same study also observed that

> Most officials come out of the local construction industry trained as members of building trades . . . or as general contractors. . . . It is not surprising that inspectors by work and social habit are tied to their localities. The officials themselves acknowledge that their most frequent work contacts are with local builders, local building material suppliers, local architects, and local engineers. Their social relationships follow the same pattern . . . Thus, the parochial view is reinforced; it is seldom modified by contacts with people outside the community who might hold more cosmopolitan views on construction technology . . . The evidence indicates that building officials are sensitive to both the political structure and the interests of the construction industry in their communities.

In the recent report of the Working Group on Earthquake Hazards Reduction [Steinbrugge, et al., 1978], the group concluded that even professionally-trained individuals in today's world are not fully prepared to deal with natural hazards. Thus, in respect to the earthquake problem, the group concluded that

> Many universities and professional schools simply are not preparing their students to deal with the earthquake problem. Many universities, even some in 'earthquake country', are graduating structural engineers without providing them with course work on seismic-resistant design. Similarly, schools of architecture generally do not provide courses on seismic-resistant design for their students. This problem is sometimes further compounded by the fact that in many communities building officials, who are expected to enforce seismic regulations, often have less training than building designers.. . . [P]rofessionals frequently have insufficient backgrounds to incorporate the available information into their decision-making. In all of the relevant areas--seismology, geology, earthquake engineering, the social sciences--knowledge is expected to expand even more rapidly in the future.

The working group went on to recommend an aggressive, federally-sponsored program of personnel upgrading and a federally-financed program of educational services to meet these needs. The working group also focused separately on the professional preparation of land-use planners to deal with natural hazards and concluded that "professional land-use planners do not have the training or experience to understand and apply earthquake hazards information." The group noted that "few academic curricula introduce urban and regional planning students to, or train them in, avoiding or mitigating natural hazards."

Although the study team undertook no independent efforts to determine the current attributes of planning and building regulatory bodies at local and state levels in areas with high hazard risks, the foregoing suggests that such study is warranted as an adjunct to the ongoing federally-sponsored natural hazards management program. How much of the nation's past failure to develop means for curbing losses from natural hazard exposures may be charged to the oversights, limited capacities, organizational disabilities, and staffing problems of land-use, planning, program development, and building regulatory agencies at local and state levels cannot now be judged; but certainly these disabilities may well have played a part in bringing about the current national situation.

Economic Constraints

Another set of factors that will constrain the capacity of national, state, and local bodies to implement loss-reducing natural hazard mitigations is that which may be judged to be economic in character. Quite aside from limited tests of cost feasibility, there are other economic questions whose consideration may well be important to natural hazard management programs. Thus, it seems clear from the evidence presented in Chapter Five that many natural hazard mitigations have the potential to substantially increase both the initial and the annual amortized cost of new housing and other structures. Yet, as a result of other factors within our economy and society, the median cost of new housing starts has been increasing more rapidly than has median family income. Without belaboring this point, it seems undeniable that the nation rapidly is approaching a point where we may be pricing our housing stock beyond the reach of those who most require decent or expanded housing. To the extent that our concern for natural hazards losses triggers further escalations in the cost of housing and other structures, the existing problem may well be exacerbated.

Moreover, since logic would suggest that both the sale and rental value of existing structures may be influenced by the total supply of such structures, as well as by the cost of new and replacement facilities, increases in the cost of new structures may well exert substantial "ripple" effects throughout the entire economy, thus fueling inflationary pressures already all too apparent within the economy. This highly speculative perspective is offered, not as a definitive judgment concerning the potential impacts of natural hazard mitigations on the U.S. economy, but, rather, as a cautionary note. Project constraints have not permitted any sophisticated study of this question and, yet, the question clearly is of importance to the making of public policy in this field.

Federal Constraints on State and Local Decision Making

The characteristics of the major federally imposed constraints on state and local policy making in respect to natural hazards management were discussed in Chapter Seven.

These constraints stem primarily from: (1) the Disaster Relief Act of 1974; (2) the National Flood Insurance Act of 1968, as subsequently amended [PL 90-448]; and (3) the Coastal Zone Management Act of 1972 [PL 92-583].

In each of these acts, Congress authorized certain benefits to be bestowed upon state and local units of government, but only if specified conditions are met by these jurisdictions. In addition, provisions within this set of acts also enable federal authorities to withhold benefits to private parties and local and state governments that are authorized by other statutes in the event that the conditions contained within the set, and in enabling regulations issued thereunder, are not met by the applicant state and local jurisdictions.

In the case of the Disaster Relief Act, the major benefits explicitly authorized to be dispersed by federal authorities under the terms of the act are: (1) planning monies intended to facilitate state preparation of comprehensive disaster preparedness and prevention plans, (2) federal disaster relief funds and services that are available to qualifying communities and states upon presidential declaration that a disaster has occurred within those areas, and (3) federal funds and services for promoting the economic recovery of areas following the onset of a disaster.

Under the terms of the National Flood Insurance Act, the benefits that are explicitly made available to state and local communities are those associated with federally-subsidized flood insurance to occupants of riverine and coastal flood plains.

Under the terms of the Coastal Zone Management Act, Congress has authorized a total of $864 million for grants and loans to states and other entities for the purpose of facilitating more effective management of the coastal zone. Section 302(h) of the act states:

> The key to more effective protection and use of the land and water resources of the coastal zone is to encourage the states to exercise their full authority over the lands and waters of the coastal zone by assisting the states, in cooperation with federal and local governments and other vitally-affected interests, in developing land and water use programs for the coastal zone, including unified policies, criteria, standards, methods, and processes for dealing with land and water use decisions of more than local significance.

The act also permits states that qualify under its terms to participate more directly in license, permit, and other regulatory activities affecting the coastal zone, which are otherwise assigned by federal law to the responsibility of such agencies as the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Bureau of Land Management, the U.S. Coast Guard, and the Department of Energy.

Regulations issued pursuant to the Coastal Zone Management Act [15 CFR 923] specify that states seeking to qualify for participation under the act must develop comprehensive programs of coastal zone management, elements of which are to focus on such phenomena as floods, erosion, land stability, climatology, and meteorology. The regulations further require that states identify coastal zone areas of particular concern, including hazard areas due to storms, slides, floods, and erosion, and require states to identify the hazard potential of such areas insofar as such potential "affects reasonable and safe use of resources".

Under the terms of the Disaster Relief Act, states seeking to qualify for its benefits must develop "comprehensive plans and practicable programs for preparation against disasters including hazard reduction, avoidance, and mitigation . . ." Section 406 of the act declares that

> as a . . . condition of any loan or grant made under the provisions of this act, the state or local government shall agree that the natural hazards in the areas in which the proceeds of the grants or loans are to be used shall be evaluated and appropriate action shall be taken

> to mitigate such hazards, including safe land-use and construction practices in accordance with standards prescribed or approved by the president . . .

Under the terms of the National Flood Insurance Act, states and communities are required to develop land-use and control measures for the management of their riverine and coastal flood plains. That act, even with its more recent amendments, contains additional teeth intended to stimulate more effective flood plain management by states and local communities. Although amendments made in May 1977 removed from the earlier provisions of the act a prohibition for any federally-insured lending institution to make loans to property owners in HUD-designated flood-prone areas that were not participants in the flood insurance program--and, therefore, occupants in a "managed" flood plain--the amendment, nonetheless, required lending institutions to notify loan recipients that they would not be eligible for federal disaster relief and that the federal government could not assist individuals who undertook development in flood-prone areas without adequate flood-proofing measures. Recently, the federal government has called for comment from the public as to the content of regulations to be issued pursuant to the terms of Section 406 of the Disaster Relief Act; the full nature of federal constraints on state and local decision-making in respect to hazard zones, therefore, is not now known.

What is clear is that the federal government currently possesses considerable leverage power to influence state and local decision-making in respect to hazard zones in coastal areas and other flood plain areas and in respect to any other hazard zones whose occupants might seek post-disaster relief from the federal government under the terms of the Disaster Relief Act of 1974.

Conclusions

The following assumptions and conclusions seem supported by the materials presented above:

1. <u>Constitutional constraints on the exercise of the police power by state governments pose no serious barriers to the regulation of natural hazard exposures by these entities</u>.

In law, state governments are vested with the "police power" of government which authorizes them to adopt regulatory and other policies to protect the health, safety, and welfare of the community. So long as such enactments are directed to the accomplishment of a public purpose, observe the constitutional requirements for due process of law, do not deny to any person the equal protection of the laws, and observe the admonition that private property shall not be taken for public use without just compensation, these enactments will generally be found to be valid by the court.

Although the constitutional validity of a regulatory statute depends both on it being "reasonable" and not "unduly burdensome", these constraints are comparatively easy to meet if statutes are appropriately drafted and the facts bearing on the focal situation are clearly established. In respect to factual findings, the courts are reluctant to substitute their judgements for those of the legislature; in respect to legal questions, the courts began their inquiry with the presumption that the statute is constitutionally valid. On the whole, the burden of establishing the unconstitutionality of a regulatory statute falls upon the aggrieved party rather than the enacting legislating body.

2. No serious legal obstacles are posed to the design and implementation, by the federal government, of policies intended to "force" state and local units of government to engage in natural hazard management and regulatory programs.

The United States Congress is comparatively free to establish qualifications and conditions that must be met by state and local governments in order to qualify for the financial and other benefits otherwise authorized by statute. These qualifications and conditions may require states or local units of government to present plans or programs which demonstrate that they have initiated and will continue to enforce appropriate regulations over natural hazard exposures.

3. Legally, the federal government may, itself, adopt and enforce a limited but important set of natural hazard regulatory policies.

Under its constitutional power to regulate the flow of interstate commerce, to engage in treaty making, and to accomplish the purposes of Article III, Section 8 of the U.S. Constitution, the federal government has engaged in a wide range of regulatory activity, including, for example, the establishment and enforcement of air pollution emission standards governing discharges from fixed sources of air pollution. Within reasonable limits, the federal government may also engage in direct regulatory activity in the field of natural hazard management. Of course, it may not deal with matters of a purely local concern, nor may it engage in activities which are alien to the constitutional charges and authorizations placed upon the federal level of government.

Also, powerful political and other constraints operate to prevent the U.S. Congress from regulating matters which, by tradition, are viewed to be matters of peculiarly local or state concern.

4. Typically, local governments can engage in effective regulatory activities to control natural hazard exposures only when authorized to do so by: (a) state constitutional provisions, (b) enabling legislation enacted by their state legislatures, or (c) "home rule" grants of power from the state government.

Although municipalities are comparatively freer to enact and enforce regulatory policies than are counties, both units of government are subject to the constraint enunciated in the above statement. Both units of government may, if authorized by state government, engage in the enactment and enforcement of building codes, land use planning and zoning regulations, housing codes, and subdivision regulations. Typically, however, these regulations are applicable only to land areas within the geographic jurisdiction of the concerned local government. Thus, the applicability of a county's regulations typically would be limited to the unincorporated territory of the county, while the applicability of a municipality's regulations would be limited to lands within its corporate boundary lines. Some states have, however, vested municipalities with the power of "extraterritorial jurisdiction" which permits such cities to enforce their building, housing, and land use regulations on unincorporated territory bordering the boundaries of the city.

5. Although the legal barriers to the adoption of effective natural hazard regulatory oplicies are few and may be readily overcome, carelessly drafted, poorly poorly supported, and inappropriately focused enactments may be found invalid by the courts.

Although the courts begin their inquiry into the validity of an enactment on the presumption that it meets all constitutional tests, and although the courts are reluctant to substitute their own judgments for the factual findings of a legislative body, the courts will not hesitate to strike down an enactment if it is so carelessly drawn as to suggest that constitutional prohibitions may have been violated. Thus, regulatory statutes may not be used for the "taking of private property without just compensation" and must further meet such constitutional tests as those related to equal protection under the laws, reasonableness, and the prohibition against the imposition of "undue burdens."

6. Natural hazard regulatory policies may be directed at a large number of potentially-desired ends, including: (a) the strengthening of new and old buildings, (b) the avoidance of certain kinds of uses of specified land areas, (c) the legally mandatory purchase or offering for sale of natural hazards insurance, (d) mandatory notification of potential property purchasers or users of the hazard-proneness of a land parcel or structure on the land; and (e) restrictions on the conduct of policy-making-hazard increasing activities by individuals, corporations, business, and governmental entities.

7. The primary constraints on the adoption of effective natural hazard regulatory policies by any level of government are those of a political and social nature.

The primary impediment to the adoption and enforcement of effective natural hazard regulatory policies has to do with the "willingness" rather than the "capacity" of governmental law-making bodies to act. Typically, some political constituency must be present to advance the need for a proposed regulatory enactment, the enactment must clearly be directed at resolution of a state of affairs which is generally recognized to constitute a problem to some significant population subset, and the cause must rank comparatively high on the political agenda of the community and its lawmakers. The probability of enactment is lessened if other political constituencies are opposed to the measure. Also, lawmakers - and their constituents - seem to prefer problem-solving strategies which involve "distributive" as contrasted to "regulatory" policies.

8. Among populations at-risk of exposure to natural and other physical hazards, **avoidance** motivations are strongest among those individuals who have not previously experienced the hazard, and the primary motivation of those who have recently experienced the hazard is to support efforts aimed at rebuilding the damaged area and which enable hazard zone occupants to get on with life as it was before.

9. Hazardous events which produce multiple, rather than single, deaths and/or which inflict property damage on many rather than few persons tend to evoke more immediate and vigorous responses from policy makers and concerned publics than do the cumulatively larger losses which may be sustained by individuals one or two at a time as the result of less dramatic hazardous occurrences.

10. Individuals and groups inexperienced with natural hazards tend to exhibit more apprehension concerning them than do those who have experienced such occurrences; "Outsiders" tend to overestimate the recovery needs of disaster areas and to exaggerate the impact of a disaster on a community; and media exaggerations of disaster impacts on a community apparently increase as a function of distance from the disaster site.

11. Local officials tend to be unaware of the degree to which their communities are threatened by natural hazards, particularly non-flood hazards.

Local officials tend to resist the imposition of natural hazard management and other policies by federal and state authorities and to support the proposition that local governments should be responsible for natural hazard policy-making.

12. The contents of building code, zoning, and other community development and hazard abatement regulations at local levels appear to respond more sensitively to economic and political pressures than to objective standards of safety or health.

This conclusion, though not one independently framed by the study team, is one which has been advanced by such researchers as Field and Rivkin [1975] and Siegan [1976]. This conclusion also is one which may reasonably be viewed as having been advanced by the 1968 National Commission on Urban Problems.

13. There is a pressing need for a contemporary study to determine the staffing capacity of state and local units of government to undertake the drafting and implementation of effective natural hazard management and regulatory policies.

Various studies which have been conducted over the period of the past 15 years have suggested that the staff of local building departments and planning agencies are of such limited size, so poorly paid, and so over-burdened with a range of functions as to limit their capacity to engage in fully comprehensive and technically-sound regulatory and planning activities. Also, some observers have suggested that the prior education and training of such staff members may be inappropriate to contemporary natural hazard management and environmental quality improvement needs.

14. Additional study is needed to determine the possible broad-scale economic effects which might be produced by hazard mitigation-induced escalations in the costs of new housing and buildings.

Project constraints prevented this study from examining the possible "ripple" effects which might be induced on the economy as a result of the broad scale application of costly building strengthening strategies to mitigate the risks associated with natural hazard exposures. However, the subject is important and further study of this matter seems to be warranted.

JUDICIAL DECISIONS

1. Associated Homebuilders v. City of Walnut Creek, 4 Cal 3d 633, 484 P 2d 606 (1971).

2. Aunt Hack Ridge Estates, Inc. v. Planning Commission of the City of Danbury, 160 Co-n. 109, 263 A 2d 880 (1970).

3. Baker v. Planning Board of Farmington, 353 Mass. 141, 228 N.E. 2d 831 (1967).

4. Boise Cascade Corp. v. Gwinnett County, 272 F. Supp. 847 (N.D. Ga. 1967)

5. Boyle v. Nelsner Bros., 230 Mo. App. 90, 87 S.W. 2d. 227 (1935).

6. Candlestick Properties, Inc. v. San Francisco Bay Conservation and Development Commission, 11 Cal. App. 3d 557, 89 Cal. Rptr. 897 (1970).

7. Capture Realty Corp. v. Board of Adjustment of Borough of Elmwood Park, 133 N.J. Sup Ct. 216, 336 A. 2d 30 (1975).

8. City of Bakersfield v. Miller, 64 Cal 2d 93, 410 P. 2d 393 (1966), cert. denied, 384 U.S. 988 (1966).

9. City of Los Angeles v. Gage, 127 Cal App. 442, 274 P. 2d 34 (1954).

10. Clements v. McCabe, 210 Mich. 207, 177 N.W. 722 (1920).

11. Dooley v. Town Plan and Zoning Commission of Town of Fairfield, 151, Conn. 304, 197 A. 2d 770 (1964).

12. Gaebel v. Thornbury Township, 8 Pa. Comm. Ct. 399, 303 A. 2d 57 (1973).

13. Goldblatt v. Town of Hempstead, 369 U.S. 590 (1962).

14. Griggs v. Allegheny County, 369 U.S. 84 (1962).

15. Hadacheck v. Sebastian, 239 U.S. 394 (1915).

16. Harbison v. City of Buffalo, 4 N.Y. 2d 553, 132 N.E. 2d 42 (1958).

17. Jones v. City of Los Angeles, 211 Cal 304, 295 P. 2d 14 (1930).

18. Just v. Marinette County, 56 Wis. 2d 7, 201 N.W. 2d 761 (1972).

19. Kopetzke v. County of San Mateo, 396 F. Supp. 1004 (N.D. Cal. 1975).

20. Lawton v. Steele, 152 U.S. 133 (1894).

21. Lorio v. Sea Isle, 88 N.J. 108, 237 A. 2d 881 (1965).

22. Miller v. Schoene, 276 U.S. 272 (1928).

23. McCarthy v. City of Manhattan Beach, 41 Cal. 2d 879, 264 P. 2d 932 (1953).

24. Mugler v. Kansas, 123 U.S. 623 (1887).

25. National Land and Investment Co., v. Kohn, 419 Pa. 504, 215 A. 2d 597 (1965).

26. Oklahoma v. Civil Service Commission, 330 U.S. 127 (1947).

27. Pennsylvania Coal Co. v. Mahon, 260 U.S. 393 (1922).

28. People v. Miller, 304 N.Y. 105, 106 N.E. 2d 34 (1952).

29. Pelple ex rel. Younger v. County of El Dorado, 5 Cal 3d 480, 487, P. 2d 1193 (1971).

30. Pioneer Trust and Savings Bank v. Village of Mt. Prospect, 22 Ill. 2d 375, 176, N.E. 2d 799 (1961).

31. Potomac Sand and Gravel Co. v. Department of Water Resources, 270 Md. 652, 313 A. 2d 820 (1974).

32. Pumpelly v. Green Bay Co., 80, U.S. 166 (1871).

33. Queenside Hills Realty Co. v. Saxl, 328, U.S. 80 (1946).

34. A. H. Smith Sand and Gravel Co. v. Department of Water Resources, 270 Md. 652, 313 A. 2d 820 (1974).

35. Spiegle v. Borough of Beach Haven, 46 N.J. 479, 218 A. 2d 129 (1966).

36. In the Matter of Spring Valley Development, 300 A. 2d 736 (Me. 1973).

37. State ex rel. Arey v. Sherrill, 142 Ohio St. 574, 53 N. E. 2d 501 (1944).

38. Sturdy Homes, Inc. v. Township of Redford, 30 Mich. App. 53, 186 N.W. 2d 43 (1971).

39. Toms River Affiliates v. Department of Environmental Protection

40. Township of Farmington v. Smith, 374 Mich. 536, 132 N.W. 2d 607 (1965).

41. Turner V. County of Del Norte, 24 Cal. pp. 3d 311, 101 Cal. Rptr. 93 (1972).

42. Turnpike Realty v. Dedham, 362 Mass. 221, 284 N.E. 2d 891 (1972), cert. denied 409 U.S. 1108 (1973).

43. Vartelas v. Water Resources Commission 146 Conn. 650, 153 A. 2d 882 (1959).

44. Vickers v. Township Committee of Gloucester Township, 37 N.J. 232, 181 A. 2d 129 (1962).

45. United STates v. Causby, 328 U.S. 256 (1946).

Chapter Nine

POLICY-MAKERS, STAKEHOLDERS, AND CANDIDATE PUBLIC PROBLEMS

Introduction and Summary

In the previous eight chapters, the general and specific natural hazards problems facing the United States have been detailed. This chapter discusses the major questions confronting policy-makers as they seek to deal with these problems. These policy-makers must identify and address: 1) the public problems associated with specific situations, 2) the needs and demands of various stakeholder groups, and 3) the alternative possible solutions to the identified problems, needs, and demands.

This chapter identifies the major stakeholders whose interests are involved in either natural hazard exposures or natural hazard mitigation measures and further identifies a specific set of candidate public problems. It also outlines the considerations which might be of importance to policy-makers in: 1) deciding which jurisdiction of government should take action, and 2) choosing between competing problem-solving priorities and competing problem solutions.

The Plight of the Policy-maker

The situations to which many citizens are so casually prepared to refer as "public problems" can be remarkably difficult for the public policy-maker to define and act upon. For example, a situation, impact, or set of effects which may be defined as a problem by one group may be regarded as a solution by another; one person's cost can be another person's benefit; an action which solves one problem besetting a given group may impose yet a different problem on that same group. It is the function of the policy-maker to resolve these dilemmas; to determine whose interests are to be served -and to what extent-, and whose are to be ignored -and to what extent; who is to receive a benefit, and on whom is a cost to be imposed; when is it appropriate to act, and when is it best to do nothing.

Problems do not occur apart from real time and space. They affect real people, at some time, in some real location, under some real condition. However, most problem situations are not well-defined; they tend to be characterized by clusters of related phenomena. In such instances, it is necessary to specify problems carefully so that they can be dealt with. The problems must be operationalized; that is, they must be defined in terms of what the disvalued attributes of a situation are and how important those elements may be to specific people in specific places under specific conditions.

The first matters to consider in defining problems operationally are what potentially adverse impacts are occurring, who is being affected by those impacts, the geographic areas within which the impacts are being felt, and the values that are being affected or are otherwise involved in these situations.

<u>Who is Affected?</u> Who or what is being affected by some set of impacts or effects? Home owners? Renters? Investors? Employers? By specifying as precisely as possible who is affected, one begins to specify the possible character of the problem. If it is residents of the Gulf Coast or farm families in Kansas, then one can begin to add a geographic dimension to the analysis. By assessing how many people are affected directly and how many are affected by second order effects, and how many can be expected to be affected in the future if current trends continue, ultimate definition of the problem is further operationalized.

<u>What is the Extent of the Impact?</u> With natural hazards, as with most other situations with which public officials concern themselves, there is a geographic dimension that can be delineated. Wisconsinites don't worry much about being injured by hurricanes and earthquakes, Southern Californians don't worry much about tornadoes and ice storms. Impacts and potential problem situations may be defined in terms of specific types of locations, such as all inner cities or all peripheral suburban areas; or they may be location-specific, such as the Gulf Coast, the Atlantic seaboard, or the Pacific Coast. They may be confined to coastal counties, and within such counties to specific zones such as tsunami inundation areas.

Which Values are Being Affected? It is one thing if a household is inconvenienced. It is quite another if a member of that household dies or is threatened with death. In order to help specify problems, we consider which values are being affected by some impact or effect and with what intensity. Among values -- or things that are valued -- are economic, physical, and mental well-being. Effects on values may range from minor inconvenience to severe deprivation. We may be able to tolerate a fairly large number of persons being slightly inconvenienced, when we would not tolerate situations where several are likely to be killed.

What Will Happen if Nothing is Done? It is important to incorporate a time dimension when seeking to define public problems. In most instances, it is possible to forecast what is likely to happen in a situation if current trends continue and if no policies are changed. Surprisingly, perhaps, no action is sometimes preferable to some action. A principal question to ask is whether the situation will get better or worse all by itself, without any additional public action. How much better or how much worse would the situation become without additional action? Is there a significant benefit to acting now as opposed to acting at some later time? That is, is it possible to exert a small amount of leverage at this time on the impact-causing or problem-causing system that will have significantly greater influence on mitigating the situation than leverage exerted at some later time, or that will produce fewer unwanted side-effects than later action of some other type.

What are the Elements of the Suspected Problem-Causing System? Mitigating the effects of natural hazards exposures requires intervention in extremely complex social, geophysical, and technologic systems involving the natural environment, social interaction, and the distribution of costs and benefits. As a general rule, it is better not to intervene in a system if one cannot accurately predict the consequences of such intervention. Unless one understands the cause and effect relationships within a system, intervention can lead to adverse consequences and to unanticipated and undesirable byproducts that may far outweigh the intended consequences and that may sometimes be sufficient to lead to total destruction of the system being influenced. Therefore, it is critically important to understand situations in their systemic relationships -- how they fit together, what causes what, and the extent to which interdependencies exist. If one does not understand systemic interrelationships, then it is impossible to predict, with any degree of certainty, the consequences of action or inaction. Unless the probable consequences of a recommended action are known, then it does not make sense to implement that recommendation.

Where one does not understand systemic relationships or where the probable consequences of action are unknown, then it makes sense to conduct research to learn more about those systems. If one is in doubt about what the real problems are - and what causes them - the best action may involve the development of further knowledge about the system.

Can the Impacts of Some Obvious Solutions be Predicted? Frequently, this preliminary stage in a policy-maker's examination of a situation can yield suspicions or assumptions concerning some major or obvious types of possible solutions. A listing of these can then be used to make some guesses about the impacts that may be produced through use of such solutions, who will experience them, to what extent, where, and what values may be affected by those impacts.

All of these inter-related, first-pass inquiries into situations in which "impacts", from some set of causes have been observed are intended for but one purpose: to gain some insights as to who is being affected - or is likely to be affected as a result of problem-solving efforts - and what values, motivations, attitudes and interests of these parties are likely to be of governing importance to the specification of selected impacts as being "problems". It is this process which leads one to the identification of stakeholder groups.

Stakeholders in Natural Hazard Policy

As discussed in Chapter One and as shown in Figure 1-2, all problems may be said to be the product of four factors: human perceptions of empirical reality; human desires and expectations for the future; values that justify and define the desired future; and the human perception of gaps between the desired future and the present. Whenever a gap has been perceived to exist between a desired and a perceived state of affairs, and whenever that gap has been disvalued by the observer, then a problem may be said to be present. Thus, any responsible analytic and intendedly value-neutral effort to identify candidate lists of public problems must at some point reflect a comprehension of the distinguishable groups of individuals whose interests are involved in the situation under analysis. Only by comprehending the characteristics of and distinctions between these groups may the analyst be led to tentative but intendedly objective assumptions concerning how each of those groups may perceive the value factors present within the examined situation. It was, therefore, out of the above-described conceptual perspective that the list of stakeholder groups was identified and the selected comments regarding each are offered. Our interest was not in judging the factual or value merits of the motivation and activities of any group but rather in sketching -- however briefly -- some possible key attributes of the group that might influence the final social resolution of the following questions: What are the public problems that are associated with the exposure of people and property to natural hazards? What are the problems that are associated with efforts to mitigate the risks associated with such exposures? What are the ascendant questions of fact and value that inevitably will be required to be considered by policymakers? What are the political and social factors that will constrain the efforts of any given group of value holders to operationalize their values and reality perceptions respecting natural hazards through the vehicle of the American public policy system?

The search for the possible public problems which may be imbedded in those situations involving either the exposure of people and property to natural hazards or attempts to control such exposures may be facilitated through a focus on thirteen possible stakeholder groups:

1. <u>Populations currently at risk of exposure to hazardous natural events</u>.

For each of the nine natural hazards identified in this study there is a companion set of identifiable hazard zones within the United States, the residents of which may be viewed as being at risk of experiencing the consequences associated with the occurrence of the hazard. The sum of the individuals who are in residence within these zones, or who own property, or have other financial interests within the zones, may be viewed as constituting the current population at risk of exposure to hazardous natural events. Clearly, this major stakeholder group consists of at least two component sets of parties: (a) individuals who currently are exposed to the hazards as a result of voluntary choice on their part, and (b) parties who are involuntarily exposed to the hazards. The former group includes those who, having knowledge of the fact that they were entering into or remaining within a hazard zone, nonetheless choose to do so; while the latter includes parties who: (a) either entered into or are remaining in the hazard zone out of ignorance concerning the risk they are running, or (b) are aware of the risk they are running but lack an ability to remove themselves from the hazard zone because of such factors as the demands of their employment or their financial inability to move elsewhere.

No independent research was conducted by the study team to assess the size of these two groups of risk-takers in respect to any hazard zone. However, other research suggests that substantial numbers of individuals who risk exposure to hazardous events are ignorant of the risk they are incurring. Thus, studies by White, et al. [1958], Kates [1971], Roder [1961], and Burton, et al, [1965] suggest that a significant fraction of occupants of riverine flood plains are comparatively unaware of the risks they are running and of the adjustments they may make to reduce those risks, whereas residents of coastal areas exhibit comparatively good knowledge of the risks they are running and of the effects of past storms. Mileti, Drabek, and Haas [1975] suggest that "most persons simply do not know the character and extent of the hazard(s) for the area in which they reside or work". They further comment that "realtors and civic leaders tend to suppress discussion of flood hazards, refuse frequently to recognize, even privately, the dangers of encroaching development, and sometimes reject flood protection works to avoid admission of the hazard's existence." Although much more needs to be known concerning this subject, it seems safe to state, especially with regard to less studied hazards (i.e., expansive soil), that comparatively few occupants of significant hazard zones are fully aware of the magnitude of the risks they are incurring and of the adjustments which they may make to mitigate those risks. Similarly, it seems clear there is little impulse on the part of sellers and transferors of property to inform property purchasers and users of the risk they are running by locating within a hazard zone.

The threat of a substantial loss of property or life is faced by occupants in many hazard zones, such as high-frequency coastal and riverine flood plains, tsunami inundation zones, and tornado-prone areas. Expansive soils, landslides, earthquakes, and other hazards all exhibit varying annual expected loss burdens to occupants of the appropriate hazard zones. [See Chapters 4 and 6]. As noted in Chapter 8, however, hazard zone occupants who have experienced the consequences of hazardous occurrences do not -- in any great numbers -- exhibit a willingness to remove themselves from the hazard zone. Instead, they wish to get on with life as it was before the event occurred, tend to deny that a recurrence of the event will heap any substantial consequences upon them, and seek support from government and other parties to make the area "safer" should the future bring a recurrence of the event.

2. Investors in hazard zone land and structures.

Owners of developed lands within hazard zones have a keen interest in maintaining and accelerating the value of their holdings. To the extent that notifications to potential hazard zone property purchasers shrink the market for such properties, it seems likely that investors would oppose these measures. Similarly, it is not difficult to imagine that owners of such properties would prefer the use of area protection systems to mitigate against the risk associated with natural hazards, particularly if all or part of the costs of such protective works are externalized to parties outside the hazard zones.

Similar comments may be made in respect to undeveloped lands within hazard zones. Since many hazard-prone lands - particularly those on hillsides and in coastal and riverine flood plains - may be blessed with a high-than-normal proportion of scenic and recreational amenities, it is not difficult to imagine that the potential rewards for development of such lands may already have led to much land speculation within such zones. Major opposition to hazard zone land planning and hazard management schemes may be expected from such parties. Moreover, to the extent that the interests of land speculators coincide with those of businessmen and other economically motivated parties whose future economic well-being may be tied to rates of development within hazard-prone areas, it can be expected that highly organized and vocal opposition will emanate from such quarters in respect to proposed hazard zone avoidance and risk reduction schemes.

3. Potential future occupants and investors in hazard-prone lands and structures.

Three demographic facts about the U.S. population suggest the quantitative importance of this stakeholder group: (1) the population is growing older and the proportion of the population above the "working age" is increasing; (2) the population, in all age groups, is increasingly mobile and given to comparatively frequent changes in their place of residence; (3) much interstate migration has been occurring, particularly from inland to coastal and from cold weather to warm weather climates.

As noted above, many high hazard zones exhibit a higher than normal mix of biophysical and recreational amenities. Precipitous and slide-prone slopes may offer occupants stunning vistas of cities and natural terrain; coastal and riverine flood plains may offer relief from the congestion and polluted air of cities and easy access to water-based recreational activities of a wide variety; and mountain vistas and easy access to a variety of recreational areas may be the rewards of those who enter into areas of high seismic activity. These potential lures to entry into areas marked by an abundance of "high hazard zones" may be accompanied by an absence of knowledge of the potential purchaser or resident concerning the characteristics of the hazards within the area and the magnitude of the risks which are incurred by occupants within those areas. Similarly, the types of adjustments which may or should be taken by hazard zone occupants may be totally unknown to such individuals. The conviction that a "benevolent and all-knowing government" will protect the citizen from harm may dampen the concern of those who have some meager knowledge of the hazards associated with a potential living or working place, and such groups may find it inconceivable that the government would permit their entry into areas where there are substantial risks.

The findings which led to the adoption of the Interstate Land Sales Act might well be considered as evidence in support of the assumptions offered above. Numerous property transactions are made within our society by parties who, imprudently and at great risk to themselves, place their faith in the integrity of land developers and property sales enterprises.

It is to the knowledge, deficiencies, and possible choices of this group of stakeholders that evidence and proposals concerning hazard zone avoidance might well be more properly and directly addressed.

4. Visitors or workers in high-hazard zones.

Although the permanent resident population of U.S. central cities has been declining, it is very likely that the "non-bedroom," transient populations of the same places have been increasing. Workers, shoppers, and tourists clog the streets of major central business districts during daytime hours throughout the nation, while conventioners, theatergoers, window-shoppers, and urban entertainment seekers may be found in great numbers in the same places during the evening hours.

Hospitals, nursing homes, and places of work draw hundreds of thousands of transients into potentially hazardous areas during selected hours of the day.

Most of the deaths produced by the San Fernando earthquake of 1971 occurred within a Veterans Administration hospital whose occupants were drawn to the facility out of a concern for, rather than a rejection of, their longevity.

Scenarios depicting the plight of the above population subsets are not difficult to write. Surrounding the high-rise megastructures of many cities in seismically active areas are literally thousands of individuals each noon hour. Imagine a high magnitude earthquake which rocks and stresses the structures, releases parapets from their mountings, shatters the acres of glass enclosing the buildings and sends tens of thousands of sharp and heavy missiles down upon the unwary population below. Or, imagine the hikers and campers in the inundation area below Teton dam in Idaho at the time of the dam failure, or the vacationers jammed into a seashore hotel in a tsunami inundation area. There is no end to the examples one may cite.

Ignorance of their risk-taking, trust in the protecting influences of government, and a concern for the objectives and interests of the moment are more likely the concerns and perspectives of this group than the manipulation of some risk-taking calculus.

5. Insurers and reinsurers.

Tax code-enforced restrictions on maintenance of liquid reserves, problems associated with the non-liquidity of investments, and the sheer magnitude of the episodic losses which may be sustained during a major hazard catastrophe constitute severe impediments to the willingness and capacity of insurers and reinsurers to engage in potentially-needed risk-distributing systems for occupants and investors in high-hazard areas.

6. Second home owners and developers.

In recent years both the absolute and proportionate number of second homes in the United States have been on the increase. Increased affluence among some segments of U.S. society and increased discretionary income has fueled this trend. Much of this second home development has occurred in high hazard areas, such as the coastal flood zone. Members of the study team have examined, on-site, several colonies of second home developments along the Gulf Coast. One such colony, located on the Bolivar Peninsula near the Houston metropolitan area, is in a site which has been subject to frequent devastating storm surges and hurricane winds. The major fraction of the developed properties were given over to "weekend" and vacation cabins, virtually all of which were elevated several feet above ground level. Most, however, were observed to be structurally inferior construction with large spans between floor joists, unfinished interior walls, poor wiring, and a minimum of structural amenities. Although no scientific sample of cabin owners was drawn in this colony, discussions with several indicated their keen awareness that their properties were located in a high hazard area and most reflected little concern over this fact. The typical view was "when the next hurricane strikes, we'll simply rebuild." Several expressed the view that low-cost loans from the government would aid them in the venture, and several indicated that their existing cabins had been constructed in part with debris scavenged from the area after the last destructive storm.

It would seem prudent to view second-home owners as a distinctly different group of stakeholders than those who are in permanent residence within a high-hazard area. Similarly, second-home owners may well be viewed as consisting of two major groups: those who frequently rent their properties to others and those who reserve their second homes primarily for use by their family members. The interests of both groups clearly will be influenced both by the risks associated with hazard exposures and by the consequences associated with rigid, legally-enforced risk mitigating requirements.

7. Local policy makers.

As noted in Chapter 8, the local policy maker rides the horns of a dilemma. On the one hand, the ethic of representational government decrees that he or she faithfully represent the views of the electorate, and on the other hand the interests of countless other parties may be tied up and adversely impacted by the prevailing views of that electorate. Non-voting second-home owners, the interests of potential future residents, the interests of outside investors, and the interests of vacationing and transient populations may be affected by local policy-making decisions; but the local policy maker is held accountable only to the resident electorate. Similarly, the policy maker - particularly in small jurisdictions - is frequently not a full-time or technically-trained individual. He or she is beset by competing demands from adjoining and higher jurisdictions of government, from the variety of constituents to which he or she is accountable, and is asked to make decisions involving complex questions of facts and values which cut across numerous technical and scientific fields.

8. Financial institutions and mortgage guarantors.

Whether their seats of business activity are inside or outside hazard zones, financial institutions and mortgage guarantors clearly have a stake in the structural integrity and life span of buildings located within hazard zones. The costs and benefits associated with mitigations intended to protect and extend structural life - at least through the life of the mortgage - are clearly of concern to these enterprises.

9. Tax-paying subsidizers of hazard mitigations.

Taxpayers within and without hazard zones have been prolific sources of funds for the construction and operation of intendedly hazard-mitigating facilities. Taxpayers within hazard zones may support, through their tax payments, the construction and operation of local flood protection works; while taxpayers far removed from hazard zones may contribute to the pools of money which are transferred from county to county and from state to state in order to provide the major area protection facilities to which local systems are linked.

The many recent battles which have been fought at the local level over bond issues and property tax rates suggest the lively nature of taxpayer inquiry that may be directed, at the local level, to projects of general benefit to the community but which impose tax burdens on the members of that community. How many major hazard-mitigating area protection facilities would now be provided were the primary and intended local beneficiaries of such projects to bear the entire burden of costs associated with such works cannot now be quantitatively estimated. However, the California "Proposition 13" syndrome seems now to have become a growing national phenomenon; general taxpayer concern over mounting tax burdens is both a present and probable future fact of public policy within the United States. Of course, there are no major, popularly-supported, and aggressive national constituencies concerned with this matter, although at numerous local sites throughout the United States, they can be identified and the consequences of their public activities more directly assessed.

Each of these major subsets of taxpaying citizen groups constitutes a theoretically distinct stakeholder group whose potential interests, perspectives, and activities may well constrain future policy making targeted on the management of natural hazards.

10. Local and state planners and building officials.

As noted in Chapter 8, respectable publications offered over the past decade have suggested the large knowledge deficiencies, and technical assistance and training requirements of this group of essentially underpaid, but extraordinarily important officers of local and state governments. Wedded to their local turf and to the interests of their local communities, this group of stakeholders - like local policy makers - is beset by numerous competing demands from adjoining and higher jurisdictions of government, many of which are abundant in their procedural (as contrasted to their substantive and technical) content. Limited by time, interest, constituency requirements, past training, and by their current willingness and capacity to acquire knowledge concerning new subjects, a major burden of future natural hazard management activities will fall upon this group. Far too little is known about the characteristics and perceived needs of these stakeholders, but it seems safe to suggest that their needs are large and - as yet- essentially unsatisfied.

11. Advocates of environmental protection and conservation.

The popular outpouring of concern for environmental quality and the renewed interest in resource conservation and protection of the natural environment which characterized the late fifties and sixties has been wedded generally to natural hazards management policy concerns. Those who wish to protect estuaries, the natural habitats surrounding rivers and coastal zones, or who wish to extend the opportunity for recreational pursuits in essentially primitive areas,find their interests conjoin with the interests of those who - for other reasons - wish to engage in more vigorous management of properties within high hazard zones.

It seems prudent to recognize the possible differences in motivations which may characterize the activities of this stakeholder group and the possible propensity of members of this group to place emphasis on the hazard potential of an area when the real interest is in the preservation of its primitive character.

To the extent that a constituency for natural hazard management policies must be developed as a necessary condition for further public activity in this area, advocates of environmental protection and conservation may well constitute one of the focal groups around which such constituencies may develop.

12. Researchers and professionals in the field of natural hazards management.

Within recent years a growing number of professionals, researchers, regulators, engineers, and officials have concerned themselves with the identification, assessment, and control of natural hazards. To the extent that members of this group—like members of other groups that are oriented toward other ends and interests-are committed to and involved in the subject matter of their studies and activities, it seems safe to suggest that some imbalance in their perspectives may take place. To some extent each of the professions and fields of inquiry and practice functions with its own set of "blinders" and tends to overstate the importance of its activities.

In an adversary-like process, groups with different interests contest with each other for available public resources and for public support for their activities. Hyperbole, imbalanced public expressions, and other similar manifestations of their focal concern may thus come to characterize the outputs of the group. This very human and unavoidable propensity nonetheless may present hazards to fully-rational and comprehensive public policy-making that is intendedly oriented toward the maximization of public benefits per unit of available public resources.

The possible characteristics and motivations of the stakeholder group should therefore be kept in mind as the task of acquiring new information concerning all types of environmental hazards, all risks to life and property, and all threats to an expanded quality of life witnin this country goes forward. It seems not imprudent to suggest that mechanisms might well be employed to insure that the conceptual structures and policy perspectives emerging from the several contesting groups are faithfully and objectively integrated into some responsible and comprehensive whole so as to better and more professionally serve the needs of the concerned public and their elected policy leaders.

13. Code writers and criteria developers.

As noted in Chapters 7 and 8, numerous groups are engaged in the development of model building codes, suggested planning and zoning ordinances, and other documents which are widely utilized in official policy-making efforts at local, state, and federal levels. In this effort the assumptions, perspectives, and motivations of numerous individuals play important roles in the quality, efficacy, and cost-feasibility of the outcome. Functioning in a world of imperfect knowledge, much emphasis is placed on past experience and informed guesswork. The need to empirically verify the assumptions upon which such documents reside may be of far less importance than "getting the job done."

Candidate Public Problems

In general, it may be said that the rational capacity of the public policy system may be increased if that system is provided with two types of inputs: public problem analyses and public policy analyses. Problem analyses identify: (1) problem states of affairs, (2) networks of causes and effects to which these states are linked, (3) underlying values associated with the states, and (4) value-holders and problem-experiencing populations and areas. Policy analyses identify: (1) alternative problem-solving strategies and policy choices, (2) criteria for the selection of policy alternatives, including those of a political, economic, ethical, and technical character, (3) decision-influencing constraints, and (4) the payoffs, outcomes, and side effects that may be expected from each policy alternative.

As noted above, the states of affairs that are conventionally referred to as "problems" are as much a product of human values and of human perceptions as they are of the empirical reality to which they are presumed to relate. Because these states of affairs require acts of human valuing, they must be viewed by an analyst as being potentially different from the states of affairs that may be identified objectively as "impacts", "consequences", or "effects". Objectively, an analyst may state that the effect of activity "A" will be to increase the cost of product "B" by an amount "C" to a consumer "D" and therefore consume "E" percent of "Ds" family income. Whether that increased cost produces a "problem" for "D" is a question that hinges on the values and reality perceptions of "D" himself, or some other value-holding party who presumes to fix the values by which the affairs and life situations of others are to be judged.

Moreover, as noted in Chapter One, there may be further important distinctions to draw between the class of events that are viewed as "problems" and those that are viewed as "public problems". In our society, not all problems are viewed as being public problems, nor are all public problems necessarily placed on the agenda for public policy action. Some are simply acknowledged as being extant but as being either too trivial or too politically infeasible to warrant the concern of the community and/or government. These distinctions, too, are based on resolution of mixed questions of fact and value.

Accordingly, considerable peril is faced by the analyst who presumes to state what "public problems" are associated with a particular situation or set of situations under examination. For this reason, the following list is to be viewed as consisting of candidate states of affairs each of which may, by some significant group within the public or the public policy system, be viewed as constituting a public problem.

The list of candidate public problems has been divided into two major sections conforming to the study team's assessment as to whether or not the focal states described may be classed essentially as being "intrinsic" or "instrumental" problems. Intrinsic states or problems are those that are disvalued in and of themselves because of their incongruence with the value orientation and/or aspirations/ expectations of some valuing agent. On the other hand, "instrumental" problems are those states of affairs that are disvalued, not in and of themselves, but because they lead to, or are perceived to lead to, still other states of affairs that are intrinsically disvalued.

Intrinsic Candidate Public Problems

Ten states of affairs have been identified by the project team as comprising the major candidate "intrinsic" public problems associated with natural hazard exposures or with efforts to mitigate such exposures. The first seven of these problems are intended to represent the publicly disvalued situations that comprise the essential justification for natural hazard management policy-making, particularly at the national level. The remaining three problem statements are intended to represent the <u>primary</u> constraints to be met by decision-making aimed at the resolution of the first seven problems. Considered as an interlocked whole, the suspected existence of these ten problems explains why the situations described as "instrumental problems" are viewed as "disvalued" situations or states of affairs.

The relationship of each "intrinsic" public problem to the several stakeholder groups identified above is depicted in Figure 9-1. In each case, the matching of a stakeholder group with a problem through the note "P" is meant to suggest that the identified group is the problem-impacted party. The note "B+" is meant to suggest that the identified group is a "beneficiary" or "affected" party whose

STAKEHOLDER GROUPS	INTRINSIC PUBLIC PROBLEMS									
	1. PERSONAL AND FAMILIAL LOSSES	2. COMMUNITY LOSSES	3. INVOLUNTARY RISK FOR MOBILE POPULATION	4. EXCESSIVE ANNUAL ECONOMIC LOSSES	5. REDUCED PROBABILITY OF MORTGAGE PAYOFF	6. EXPECTED INCREASE IN MAGNITUDE OF PROBLEM	7. COSTS TRANSFERRED TO NON-RISK-TAKERS	8. INCREASE IN COST OF OPERATIONAL REQUIREMENTS	9. POLICIES INCOMPATIBLE WITH PERSONAL OR COMMUNITY VALUES	10. IMPAIRED IMPROVEMENTS IN LIFE QUALITY
POPULATION CURRENTLY AT RISK	P B+	P B+	B-	P B+		P B+	P B+	P B+	P B-	P B+
INVESTORS IN HAZARD-PRONE LAND AND STRUCTURES	P B+	B+	B-	P B+	P B-	P B-	P B-	P B-	P B-	P B-
POTENTIAL FUTURE OCCUPANTS AND INVESTORS	B+	B+	B+	B+	B+	P B+	B-	P B+	B+	B+
VISITORS OF WORKERS IN HIGH-HAZARD ZONES	P B+		P B+			P B+				P B+
INSURERS AND REINSURERS	B+		B+	P B+	P B+	P B+	B-	B+	B-	
SECOND HOME OWNERS AND DEVELOPERS	P B+	P B+	P B+		P B+	B-	P B+	P B-	P B-	P B-
LOCAL POLICY MAKERS		P B+				P B+	B?		B-	B+
FINANCIAL INSTITUTIONS AND MORTGAGE GUARANTORS	B+	B+		P B+	P B+	P B+	B-	B+	B-	
TAXPAYING SUBSIDIZERS OF HAZARD MITIGATIONS	B+		B+	B-	B+	B+	B+	B+	B+	B+
LOCAL AND STATE PLANNERS AND BUILDING OFFICIALS		B+		B+	B+	B+		B-	B-	B+
ADVOCATES OF ENVIRONMENTAL PROTECTION		B+					B+	B+	B-	P B+
RESEARCHERS AND PROFESSIONALS		B+		B+		B+	B-	B+		
CODE WRITERS AND CRITERIA DEVELOPERS		B+		B+		B+		B+	B-	

KEY:
P = Problem-Impacted Party
B+ = Beneficiary Party
B- = Interests will be Negatively Served

Figure 9-1. Relationship of Intrinsic Public Problems to 13 Stakeholder Groups interests may positively be served by problem-solving activities, while a "B-" indicates that group interests will be negatively served by such problem-solving activities.

The failure to describe possible mitigation-induced losses to some business-oriented groups as constituting "public problems" is borne not out of any bias of the project team but out of its interpretation of what constitutes the enduring and prevailing values of the society and of our governmental and economic systems.

1. Many individuals are now in residence within natural hazard zones and are at risk of experiencing disfunctional--even catastrophic--personal and familial economic and other losses as a result of exposure to natural hazards.

In 1970, annual expected total dollar losses arising from the exposure of buildings and their contents to nine natural hazards totalled approximately $8.1 billion. These same exposures also were expected to yield 979 deaths per year, a loss of 114,000 housing units, 129,850 person-years of homelessness, and nearly 80,000 person-years of unemployment [See Table 4-1]. Approximately 33% of flood losses were sustained by less than 8.0% of the U.S. population [See Table 4-5]. At the scale of whole counties and states, annual expected per capita losses from natural hazard exposures range from nearly $220 for the highest damage rate county to only $16.86 in Vermont. Within the nation's 500 most damage-prone counties (for all natural hazards except riverine flooding), annual expected per capita losses ranged from $21.18 to approximately $220 in 1970. In terms of more finely-drawn hazard zones, annual expected losses totalled slightly more than $402 per capita for occupants of riverine Flood Zones A to C in communities not protected from 50-year floods; $121 per capita per year in the storm surge flood plains of Georgia; $24 per capita per year for the three counties exhibiting the highest average annual number of tornado strikes; $28 per capita per year for occupants in states with the highest annual expected damage rate from earthquakes; approximately the same for individuals in the state exhibiting the highest hurricane wind hazard; and $26 per capita per year for occupants of intra-county areas that are within high expansive soils zones. Occupants of 500-year tsunami inundation plains in 1970 were found to be at risk of experiencing annual expected losses totalling approximately $37 per capita [See Table 4-22].

In single catastrophic events, such as major earthquakes or hurricanes, residents in the counties experiencing the highest magnitude of the occurrence were found to be at risk of experiencing per capita episodic losses in excess of $16,000 [See Tables 6-3 and 6-11].

2. Because of the substantial fraction of their population, building wealth and land area located within natural hazard zones, many whole communities are at risk of experiencing either economically disfunctional or catastrophic losses as a result of natural hazard exposures.

Although recent studies have shown that few long-term economic impacts have been incurred by communities as a result of their exposure to hazardous natural events, it is also clear that the recovery capacity of these communities has been greatly influenced by the infusion of disaster relief funds from outside areas and jurisdictions. Also, natural hazard exposures of the high magnitudes that can be expected to occur in this country in one or more major metropolitan areas have not yet been experienced during the current century.

In 1972, the Office of Emergency Preparedness reported to the Congress that, along the Atlantic and Gulf coasts, increasing population density, inadequate evacuation routes, ineffective building codes, and insufficient provision of safe refuges are increasing the probability of a major hurricane catastrophe [Office of Emergency Preparedness, 1972, p. 47]. The report noted that some states vulnerable to hurricanes do not have statutory authority to order evacuation on the scale and at the time a hurricane advisory might indicate the need for such action; that numerous local communities and large jurisdictions lack adequate knowledge concerning their vulnerability to natural disasters; that both private citizens and local public officials are not aware of the natural disaster hazards existing in the area in which they live, the likelihood of their occurrence, and the measures that property owners can take to avoid or mitigate them; that comparatively few vulnerable communities have prepared effective plans for dealing with tsunami. In a more recent report by the Working Group on Earthquake Hazards Reduction of the Office of Science and Technology Policy [Steinbrugge, 1978], it was noted that, at present, federal and state earthquake contingency planning is inadequate to respond effectively to a large magnitude earthquake in or near a heavily-populated region; that tsunami flood zones have not been adequately defined and that mitigation practices within tsunami-prone areas are deficient; that inadequate action has been taken to cope with the hazards posed by non-earthquake-resistant older structures (generally buildings constructed of unreinforced masonry) in cities at high risk of seismic disturbances; and that existing information about earthquake hazards is generally neither sufficiently detailed nor in a form that can be used in land use planning and in implementing plans for avoiding hazards and mitigating damages.

3. Interstate and intercommunity migrants, as well as out-of-area employees, customers, and visitors, are incurring a substantial level of "involuntary risk" because of their entry into, or purchase/rental of property within, natural hazard zones and because of the withholding of information from them concerning the level of risk within the area or because of a general lack of knowledge concerning those risks by both "insiders" and "outsiders".

When the general attitude of the public that "government will protect them" is combined with the high level of residential mobility, intercommunity migration, and away-from-home shopping, working, and vacationing habits of that population, and when these factors are further associated with the fact that there is an apparent low level of knowledge among hazard zone occupants--much less outsiders--concerning the magnitude and consequence of natural hazard risk-taking within the zone, it seems clear that a substantial number of non-hazard zone residents are being exposed unknowingly and, therefore, involuntarily to risk-taking within natural hazard zones. At present, those parties who sell, offer to sell, or participate in the transfer of property from one owner to another are not generally required to disclose to the possible new owner information concerning the hazard-proneness of the property.

4. Annual economic losses in excess of the probable annual amortized costs of mitigations are being experienced by parties located within many natural hazard zones.

In approximately 230 U.S. counties, the application of building-strengthening strategies is capable of reducing annual expected natural hazard losses by amounts greater than the annual amortized costs of the mitigation [See Table 5-22]. In numerous riverine flood zones, coastal storm surge areas, and other hazard zones, combinations of building-strengthening, area protection, and avoidance strategies also may reduce annual expected natural hazard losses by amounts greater than the annual amortized costs of the mitigation [See Table 5-1].

Therefore, to the extent that economic "efficiency" is, itself, a deeply rooted value and motivation of this society, this situation, must be viewed as a public problem.

5. The probability of payoff of some loans and mortgages to private financial institutions, public entities, and mortgage guarantors is being reduced by continuing imprudent investments in high hazard zones.

The magnitude of this problem cannot readily be identified through the data generated in this study; study outputs, nonetheless, suggest that the situation described in this problem statement is real and probably expanding.

6. Unless appropriate corrective measures are taken, the above problems will increase in magnitude between 1980 and 2000.

Improvident patterns of interstate, intercommunity, and intracommunity residential change and capital investment are increasing the size of the nation's population at-risk of exposure to natural hazards. The projected increase in total natural hazard economic losses between 1970 and 2000 is in excess of the annual expected loss in 1970 [See Tables 4-1 and 4-2].

7. A significant fraction of the costs of voluntary and involuntary natural hazard risk-taking is being transferred to the general body of non-risk-taking taxpayers.

Because of the numerous aids and subsidies contained in current federal natural hazard mitigation and relief legislation, a significant and growing national annual cost of natural hazard exposures is being transferred to parties who do not reside within the hazard zones in which these losses are incurred. Although the 1936 Flood Control Act provided for cost sharing by state and local governments in federally-initiated flood control projects, that provision was dropped shortly after the enactment of the statute, and the bulk of flood control costs subsequently have been borne by the general body of taxpayers. Similarly, numerous occurrences now qualify for disaster designation under the terms of the Federal

Disaster Relief Act, and parties experiencing losses during such events are entitled to a wide variety of benefits from the federal government, including forgivable loans, interest-free loans, direct recovery services, and federally-financed reconstruction of community lifelines and other infrastructure.

The availability of these benefits has sometimes been cited as constituting an incentive for individuals to enter into high hazard zones and as a deterrent to local and personal initiation of more economical hazard avoidance, hazard mitigation, or hazard adjustment activities.

8. Purchasers and users of property face an escalation in the initial and annual amortized cost of such property as a result of governmentally-required building-strengthening and other hazard-mitigating requirements.

This study has made clear that overzealous, across-the-board strengthening of building codes may well increase by a substantial amount the net annual burden associated with natural hazard exposures [See Table 5-31]. Other studies performed within the past decade or so also have suggested that building code requirements in many areas may exceed the objective needs of public health, safety, and building life, and be imposing unnecessary cost burdens on a housing-hungry population [National Commission on Urban Problems, 1968; Field and Rivkin, 1975]. More recently, the Working Group on Earthquake Hazards Reduction has noted that current seismic codes do not adequately balance the risks of quake-inducing damage against the cost of applying mitigations, and further observed that some building codes do not reflect the current state of the art in respect to earthquake-resistant design.

A more careful study of current building code requirements and the empirically-defensible cost-benefit and cost-risk reduction relations implicit therein seems clearly to be warranted. However, present evidence suggests that the problem statement, as composed, is a fully-defensible interpretation of the current state of affairs.

9. The ability of individuals and whole communities to engage in courses of personal and community action compatible with their own values is threatened by

action-forcing and regulatory policies adopted by state and federal governmental entities.

From a national, regional, or state perspective, the data presented in this and other similar reports does not make it easy for any compassionate or rational analyst/observer to determine "what is right?" Indeed, the data suggests that there may be many "rights", many possible courses of action that are consistent with the objective realities of the natural hazard situation and the prevailing values of specific communities and of the nation as a whole. Decision-making by higher units of government that require uniform or near-uniform application of limited perspectives and value choices across the face of the country, therefore, run the risk of overlooking both empirical and value-oriented "acceptable alternatives" that might be applied in specific locales by men and women guided both by intelligence and good will.

A leading nineteenth century political and legal philosopher once observed that the "public interest requires that we do today what men of intelligence and good will would wish--five or ten years hence--had been done". From this perspective, natural hazard situations are so complex, the values contained within them so numerous, and the possibilities for action so various, that it seems clear that there may be many "rights", and many ways to fulfill the "public interest" as that interest is perceived in many specific places and in varying specific times.

10. Achievable improvements in human longevity and life quality are being impaired by current and possible future allocations of public resources.

Like other nations, the United States is plagued by a long list of public problems and by an expanding agenda of public wants and goals. Given limited knowledge concerning the costs and benefits associated with the expanding variety of policies and actions that may be taken in respect to these problems and goals, beset by competing claims from politically-organized groups, and further limited by objective evidence and perceptions concerning the interrelationships between the whole, the major actors within the American public policy system are now--as in the past--in continuing danger of misallocating limited available public resources.

As compared with other problem situations, it is easy for researchers, activists, regulators, and technical advisers to overstate the importance of the phenomena that are the focal points of their professional lives. So it is in respect to natural hazard exposures.

It seems clear that additional study and information synthesis should take place to identify and priority-rank the numerous natural and man-made hazard zones within which both resident and transient populations are at risk of experiencing consequences of various magnitudes, frequencies, and importance to themselves and to the nation as a whole. If our system-spanning national objectives are to achieve the greatest extensions in human longevity, the maximum improvements in life quality, and the largest gains in the economic efficiency of our society per million dollars of available public resources expended, then the subject of human hazard exposures would profit from inquiry conducted within larger contexts.

To the extent that the "Proposition 13 syndrome" is one that may beset most regions of the country and all levels of government, then it may well be that public expenditures at all levels will be constrained more severely in the future than they have in the past and that the need for such comprehensive problem assessment and policy planning will be even larger than intimated here.

Instrumental Candidate Public Problems

Situations or states of affairs whose existence contributes to the occurrence of, or impedes the mitigation of, "intrinsic" problem states are here referred to as "instrumental" public problems. In these terms, their solution is justified only in terms of the extent to which they contribute to the solution of "intrinsic" problems. The assumed relationship between the candidate "instrumental" problems identified below and the "intrinsic" problems identified above are depicted in Figure 9-2.

The candidate list of instrumental problems was developed using the project generated data and the conclusions and recommendations of both the government and recognized experts in the field as the principal guidelines.*

*see Advisory Commission on Intergovernmental Relations, 1966; National Commission on Urban Problems, 1968a, 1968b, 1969; Office of Emergency Preparedness, 1972; Office of Disaster Relief, 1976; United States Water Resources Council, 1976; Dacy and Kunreuther, 1969; Field and Rivkin, 1975; White, 1974, 1975, 1976; Williams, et al, 1968; and Wright, et al, 1978.

CANDIDATE INTRINSIC PROBLEMS	CANDIDATE INSTRUMENTAL PROBLEMS: 1. INADEQUATE PROGRESS IN HAZARD ZONE MAPPING	2. INADEQUATE DATA FOR DEVELOPING MITIGATION CRITERIA	3. INADEQUATE DATA TO ESTABLISH COST-LOSS REDUCTION RATIOS FOR MITIGATION	4. INADEQUATE INFORMATION TO SUPPORT MODEL BUILDING CODE REQUIREMENTS	5. LOCAL BUILDING CODES OF UNCERTAIN QUALITY CAN BE INCOMPATIBLE WITH NATURAL HAZARDS MANAGEMENT	6. LIMITED EFFECTIVE LOCAL PLANNING AND IMPLEMENTATION	7. LOW LEVEL OF LOCAL NATURAL HAZARD PERCEPTIONS	8. WEAK CONSTITUENCY FOR NATURAL HAZARD POLICY	9. POLICY FAVORS FINANCIAL ASSISTANCE AND AREA PROTECTION WORKS	10. INADEQUATE COORDINATION OF FEDERAL NATURAL HAZARD PROGRAMS	11. LIMITED OPPORTUNITY TO PURCHASE HAZARD INSURANCE	12. LOW PUBLIC INTEREST IN NATURAL HAZARD INSURANCE WHEN AVAILABLE	13. FEDERAL RESEARCH EXPENDITURES NOT MATCHED WITH ANNUAL EXPECTED LOSSES
1. INDIVIDUALS RESIDING IN HAZARD ZONES	++	++	++	++	++	++	++	++	++	++	++	++	++
2. WHOLE COMMUNITIES AT RISK OF LOSS	++	++	++	++	++	++	++	++	++		++	++	++
3. VISITORS INCUR INVOLUNTARY RISK	++	++	++	+	+	+	++	+	+	+	0	0	+
4. LOSSES EXCEED ANNUAL MITIGATION COSTS	+	++	++	++	++	++	+	++	+	++	++	++	++
5. REDUCED PROBABILITY OF MORTGAGE PAYOFF	+	++	++	++	++	++	+	+	+/-	+	++	++	+
6. PROBLEMS WILL CONTINUE TO INCREASE IN MAGNITUDE	++	++	++	++	++	++	++	++	++	++	++	++	++
7. COSTS TRANSFERRED TO NON-RISK-TAKING TAXPAYERS	0	0	+	+	++	+	0	-	++	++	++	++	0
8. POLICIES INCREASE PROPERTY COST	+	+	+	++	++	+	0	0	-	+	++	++	+
9. POLICIES THREATEN INDIVIDUAL AND COMMUNITY VALUES	++	++	++	+	+	+	++	+	+	++	0	0	+
10. IMPAIRED IMPROVEMENTS IN HUMAN LONGEVITY	+	+	+	++	++	+	++	0	+	+	0	0	+

KEY:

Effect of resolution of instrumental problems on the resolution of intrinsic problems.

- ++ Very Supportive
- \+ Supportive
- 0 No Effect
- \- Detrimental

Figure 9-2. Relationship Between Intrinsic and Instrumental Candidate Public Problems

1. Hazard Zone Identification, Mapping, and Classification: The past rate of progress in identifying, mapping, and classifying natural hazard zones has been inadequate; too few zones have been mapped, and inappropriate or incomplete information has been provided map users concerning the frequency and magnitude of hazard occurrences within such zones.

Timely, effective, and rational natural hazard management activities are dependent on the availability, accessibility, quality, understandability, and comprehensiveness of information concerning the metes and bounds of local natural hazard zones and their component sections (classified by frequency or magnitude of occurrence), and the frequency and magnitude of hazardous occurrences expected within the various sections of the zone, and concerning the hazard-relevant geophysical characteristics (such as soil type) of elements of the several sections of the zone.

Thus, the Working Group on Earthquake Hazards Reduction has observed that current seismic risk maps are in conflict with each other; do not present alternative levels of risk; do not adequately incorporate "engineering considerations"; and are not available for a sufficient number of areas within the nation. The group noted that existing information about earthquake hazards is generally neither sufficiently detailed nor in a form that can be used in land use planning and in implementing plans for avoiding hazards and mitigating damages. Agreeing with the Office of Emergency Preparedness, the group noted that tsunami flood zones have not been adequately defined. Virtually all those who have examined natural hazard occurrences within the United States have noted the need for hazard zone and risk mapping and have commented on the general lack of such information. This information deficiency may well lie behind the generally uninformed level of public and policy-maker understanding of natural hazards within local communities and even larger jurisdictions. In respect to the mapping of riverine flood plains, the General Accounting Office has noted the formidable mapping problems associated with meeting the statutory objectives of the Federal Flood Insurance program [Comptroller General of the United States, 1976].

Cost requirements associated with high-quality and timely hazard zone mapping activities, together with the human and technical resource requirements associated with this function, suggest that central federal priority-setting should take place in respect to this matter.

Whatever the final priorities may be, it seems appropriate to suggest that they should be fixed in consonance with the annual expected losses associated with exposures within the various types of hazard zones, the sizes of the populations currently at risk, and with the growth in losses and population exposures expected between now and the year 2000. Moreover, it may be well to reconsider the appropriateness of the past federal role in this process and to place greater emphasis on federal establishment of criteria and standards to be employed in such mapping and zone-classifying activities, as contrasted to direct federal--or federal contract financing--of these operations. Expanded roles for state and regional planning agencies are not difficult to conceive, nor are requirements for public hearings and technical review of map outputs prior to their official publication and endorsement.

2. Inadequate methods and data now are available for use in operations targeted on the development of empirically defensible mitigation criteria.

As utilized in this problem statement, the term criteria is meant to refer to a predictive or descriptive statement that describes the level of loss or damage reduction at any given level of intensity or frequency of hazard occurrence that may be derived from use of any specified mitigation. For many hazards, such as expansive soils, the current data base is woefully inadequate. For almost all hazards, some additional data are required.

3. Inadequate procedures and pools of data have been provided to permit concerned technical and regulatory bodies to establish empirically-defensible statements concerning the cost-loss reduction or cost-damage reduction ratios associated with the use of specific mitigations in specific types and sections of natural hazard zones.

4. In respect to natural hazard mitigations, significant differences can be noted in the content of "model building codes"; and too little empirically-defensible information is available to support the numerous judgments that enter into the specification of "model code" requirements.

5. Local building codes are generally of uncertain quality, too infrequently reviewed and revised, and sometimes based on motivations and purposes that may not clearly be in the public interest nor compatible with the ends of rational natural hazards management.

The Working Group on Earthquake Hazards Reduction noted that some building codes do not reflect the current state of the art in respect to earthquake-resistant design and further observed that some of the model building codes may not be completely adaptable to all areas of the United States, with their different degrees of seismic risk. The group further observed that these codes do not adequately balance the risks of quake-induced damage against the costs of mitigation. They further noted that inadequate action has been taken to implement building code or other regulatory provisions intended to deal with the hazards posed by older, non-earthquake-resistant structures. Similarly, the Office of Emergency Preparedness reported in 1972 that state and local legislation has not kept pace with the growing problems of natural disasters and that "ineffective building codes" in communities along the Atlantic and Gulf coasts are exacerbating the probability of a major hurricane catastrophe in that area. The National Commission on Urban Problems reported in 1968 that "building code jurisdictions are thousands of little kingdoms, each having its own way: what goes in one town won't go in another--and for no good reason." The Commission concurred with the claim that "the provisions in codes are antiquated and outdated and that the procedures for modernizing and amending them are slow, laborious, and lacking in objective standards". The Commission was so concerned with the quality of local building codes that their recommendations called, in part, for "minimum standards below which no community might fall and maximum limits in order to prevent restrictive practices" [National Commission on Urban Problems, 1968, p. 265].

6. Local planning and building regulation departments and professional staffs exhibit limited capacity to engage in effective natural hazard policy planning and implementing activities.

The staffs of building departments at the local level generally are drawn from local construction trades, are paid extraordinarily low salaries, and--apparently on the whole--lack the time and training to engage in the technically demanding function of hazard-related building code review and planning. Similarly, land use and regional planners typically have not received academic training on subjects related to natural hazards; and even professionally-trained architects and engineers frequently exhibit the same incapacity.

Although quantitative defense of this view is rarely offered, most groups that have examined this subject seem to be in agreeement with the assumptions implicit in this problem statement. If true, the statement suggests the need for much technical assistance and training support to these staffs by state and federal entities. At a minimum, there appears to be a need for a well-executed and unbiased study of this situation.

7. There is a comparatively low level of public and policy-maker perception of the natural hazards that exist within their communities and of the consequences associated with continuing exposure to those hazards.

8. There is no apparent "political constituency" that has emerged to argue on behalf of comprehensive and rationally conceived natural hazard management policies at any level of government; but limited constituencies have developed that argue against imposition of natural hazard management action-forcing policies upon local governments by state and federal units of government.

9. The major public and policy-maker demands in respect to natural hazard management policies are tilted in favor of: (a) financial and other forms of assistance to disaster-impacted parties; and (b) area protection works funded by the nation as a whole.

10. Inadequate coordination has been provided to past and current federally conducted hazard management and hazard-related programs.

Several reports of recent vintage have noted the absence of central leadership and coordination of natural hazard management programs within the federal structure; the lack of coordination of flood plain-directed programs; and of programs intended to develop public and policy-maker understanding of the extent of the natural hazard problem and of appropriate natural hazard mitigations. According to the Working Group on Earthquake Hazards Reduction, there has been virtually no integrated coordination of federal land use planning and development programs with those more pointedly related to natural hazard exposures. Similarly, there seems to have been little integration of employment programs for the chronically or occasionally unemployed (such as CETA) with the aims of natural hazard management activities (such as removal of structures from high hazard zones).

The recent presidential announcement that accompanied the proposed reorganization of federal disaster management functions provided an acknowledgment of the need for at least a more comprehensively-and centrally-oriented organizational structure to cope with the mix of functions related to the initiation of hazard mitigation programs and to the provision of relief and recovery services after the occurrence of hazard-induced disasters.

11. <u>In general, populations at risk of exposure to natural hazards do not now have the opportunity to purchase insurance of appropriate coverage at desirable rates so as to spread the risk of their exposure-induced losses among the relevant population of risk-takers</u>.

Although federally-subsidized flood insurance is now available and even though commercial insurance against selected other natural hazards is now offered by some companies in some parts of the United States, it is not generally possible at present for property owners to purchase all-purpose natural hazard insurance coverage and, therefore, to take advantage of this means for avoiding catastrophic losses arising from natural hazard exposures. The absence of this opportunity probably directs undue attention to other methods for mitigating potentially catastrophic natural hazard losses, including those related to provision of area protection facilities and to use of building-strengthening technologies. From a cost-benefit point of view, insurance coverage may well be a better solution to some aspects of the loss problems associated with natural hazard exposures than other approaches. At the very least, insurance can be an important partner in a comprehensively-oriented loss-reducing strategy.

A variety of factors may be influencing the lack of these insurance opportunities, including some having to do with tax code constraints on maintenance of liquid reserves: the difficulties and risks faced by insurers and re-insurers in meeting the "unusual" financial requirements associated with possible catastrophic occurrences, and other similar factors. There appears to be a substantial need for a thorough, empirically-sound study of this entire subject.

12. Even where natural hazards insurance is available, public interest in the purchase of such insurance has not been particularly high.

13. Federal research and technology development expenditures have not exhibited an appropriate match with the annual expected losses associated with exposure to various hazards nor with the size of the populations at risk of exposure to such hazards.

However laudable, natural hazards research and technology development efforts within the federal structure have tended to respond to the "natural disaster of the moment" rather than to the total mix of potential natural hazard exposure problems. Thus, however well advised the research expenditures authorized under the Earthquake Hazards Reduction Act, it appears that far more attention is being given to this hazard than to other types of hazard exposures of equal or greater national importance. Thus, apparently large annual losses are being sustained as the result of property exposures to expansive soils, but comparatively little is known about this phenomenon. Similarly, too little research and technology development is being directed toward means of coping with coastal flooding, landslide, and wind hazards. The whole subject of cost-benefit relationships in building code standards has for too long been ignored; and the substantial technical assistance and training requirements of state and local planning, hazard management, and building code agencies and personnel have gone too long unattended. The reports by Steinbrugge [1978], the National Commission on Urban Problems [1968], and White and Haas [1975] provide a context for future deliberations on this subject.

However, none of the reports examined by the study team have clearly, explicitly, and rationally offered defensible criteria through which the desirability, feasibility, and priority of alternative research, technology development, and technology transfer opportunities could be judged. Certainly, such factors as the scope of the problem addressed, the need for the information, the loss-reducing potential of new knowledge, and the state of the current knowledge base are factors that should be utilized to judge such matters. Moreover, it would appear that there has been too little effort made by federal funding agencies to comprehensively assess research and other needs related to human and property exposures in all types of hazard zones, including those of natural and man-made origin. For example, all too little is known concerning the comparative risks incurred by individuals and property exposed to conditions in a variety of natural and man-induced hazard zones.

The Search For Policy Solutions

If the candidate problems identified above are those which are accepted by a policy-maker, then two other questions must quickly be addressed: (1) What priority should be given to the solution of each problem, or any component thereof? (2) What types of policies may be employed to deal with each priority problem?

Establishing Priorities

It is necessary to establish priorities because resources are scarce. When it is impossible to meet all needs, then a determination must be made concerning the appropriate allocation of resources among the problems being considered. Typically the priority question is a matter of relative emphasis, not a matter of which problem is treated first to the exclusion of others.

Generally, priorities should be based on the magnitude of the problem faced, or the ease with which the problem may be solved. More important problems should be addressed with more resources than should less important problems, and those problems which are most amenable to solution should be tackled before those which are believed to be "impossible" or highly difficult to solve.

The establishment of these priorities is as much an exercise in making "value choices" as it is one in responding to objective evidence. For example, if the total loss of life sustained by the nation is the primary criterion which is to be used by a policy-maker to judge the relative priority of natural hazard exposures, then the exposures of greatest year-to-year importance are tornados, riverine and coastal flooding.

If, however the greatest value is to be placed on the phenomena which involve the largest life loss in a single event - regardless of their frequency - then priority would have to be given to major earthquakes, tsunamis, and hurricane wind/storm surge occurrences.

If total economic loss is to be the guiding - or major modifying - criterion, then emphasis would have to be placed on wind hazards, coastal and riverine flooding, earthquakes, and expansive soils.

If the immediate technical and cost feasibility of solutions is to be emphasized, then priorities should be given to mitigation of landslides and to the future avoidance of flood zones.

If the annual magnitude of future losses is to be given greater weight than those of the present, then priority would be given to those phenomena and hazards that are associated with the largest fraction of the projected increases in natural hazard costs of all types.

In general, problems can be operationalized and their relative priorities can be determined by addressing four questions:

- How many people or how much area is adversely affected?
- How intensely are these people and these areas being affected?
- Will the problem situation get better or worse if nothing is done?
- Is the greatest gain to be derived from dealing with existing exposures or from preventing future ones?

However these priority questions may be resolved, the policy-maker will face the further task of determining the applicability of each general type of policy to each specific problem - whether of an intrinsic or instrumental character.

This report identifies several types of policies that offer a range of potential approaches to decision-makers:

1. Those intended primarily to force loss-reducing activities by state and local jurisdictions of government (action-forcing policies);
2. Those intended to stimulate citizen, group, and governmental interest in losses produced by natural hazards and to elicit voluntary state, local, and private action to reduce such losses (attention-focusing policies);
3. Those intended primarily to assist personal, familial, neighborhood, community and state recovery from the damages sustained as a result of exposure to a natural hazard (disaster recovery policies);

4. Those focused primarily on development of new knowledge concerning the subject and on the information and technology necessary to support the making and implementation of hazard mitigating policies (technology development policies):
5. Those focused primarily on transfer of knowledge to consumers, governments and others and on the development of user capacity to make effective use of that knowledge (technology transfer policies);
6. Those intended to regulate the decisions and behaviors of private parties and other governmental entities so as to bring about the reduction of losses associated with exposure to natural hazards (regulatory policies);
7. Those intended to fix responsibilities, to specify the means to be employed, and otherwise to define the restrictions to be met by federally-sponsored hazard mitigation policies and programs (system management policies);
8. Those intended to assure that other policies in the set are compatible with system goals, effective, internally consistent with each other, and in consonance with other national policies (system optimization policies); and,
9. Those focused on the acquisition and allocation of resources necessary to sustain the activities described above (investment and cost allocation policies).

The applicability of each of these types of policies to each of the candidate public problems is depicted in Figure 9-3 . As shown in the figure, and in terms of the time frame immediately surrounding the policy, a "0" is intended to suggest little or no direct impact on the problem state of affairs, a "+" suggests a high degree of problem resolution, and a "-" suggests that a worsening of the problem might result from use of that type of policy. To be noted, of course, is the fact that "avoidance"policies do nothing for those that are now exposed to hazards: the construction of a dam may do much to reduce losses for a currently-exposed population group, but serve to entice others into situations of higher risks than necessary; a federal regulatory policy may produce immediate impacts on a hazardous natural situation, but weaken the quality of intergovernmental relations and depress the capacity of local governments to deal with such situations in the future.

What seems clear from examination of the figure is: that a mix of policies are probably required, that both short-and long-term consequences should govern policy designs, that both system improvements and direct hazard reduction policies should be executed concurrently, and that no single value should govern all policy choices.

CANDIDATE PUBLIC PROBLEM	POLICY TYPE								
	ACTION-FORCING	ATTENTION-FOCUSING	DISASTER RECOVERY	TECHNOLOGY DEVELOPMENT	TECHNOLOGY TRANSFER	REGULATORY	SYSTEM MANAGEMENT	SYSTEM OPTIMIZATISM	INVESTMENT & COST ALLOCATION
INTRINSIC									
1. INDIVIDUALS RESIDING IN HAZARD ZONES	+	+	+	+	+	+	+	+	+
2. WHOLE COMMUNITIES AT RISK OF LOSS	+	+	+	+	+	+	+	+	+
3. VISITORS INCUR INVOLUNTARY RISK	+	+	o	o	+	+	+	+	+
4. LOSSES EXCEED ANNUAL MITIGATION COSTS	+	+	+	o	+	+	+	+	+
5. REDUCED PROBABILITY OF OF MORTGAGE PAYOFF	+	+	+	o	+	+	+	+	+
6. PROBLEMS WILL CONTINUE TO INCREASE IN MAGNITUDE	+	+	+	+	+	+	+	+	+
7. COSTS TRANSFERRED TO NON-RISK-TAKING TAXPAYERS	-	+	-	-	o	+	+	o	o
8. POLICIES INCREASE PROPERTY COST	-	o	o	+	+	o	+	+	+
9. POLICIES THREATEN INDIVIDUAL AND COMMUNITY VALUES	-	+	+	+	+	-	-	+	+
10. IMPAIRED IMPROVEMENTS IN HUMAN LONGEVITY	-	+	o	+	+	+	+	+	+
INSTRUMENTAL									
1. INADEQUATE PROGRESS IN HAZARD ZONE MAPPING	+	+	o	+	o	+	+	+	+
2. INADEQUATE DATA FOR DEVELOPING MITIGATION CRITERIA	-	+	o	+	o	-	-	-	-
3. INADEQUATE DATA TO ESTABLISH COST-LOSS REDUCTION RATIOS FOR MITIGATION	-	+	o	+	o	-	-	-	-
4. INADEQUATE INFORMATION TO SUPPORT MODEL BUILDING CODE REQUIREMENTS	-	+	o	+	+	+	+	+	-
5. LOCAL BUILDING CODES OF UNCERTAIN QUALITY CAN BE INCOMPATIBLE WITH NATURAL HAZARDS MANAGEMENT	-	+	o	+	-	+	+	+	-
6. LIMITED EFFECTIVE LOCAL PLANNING AND IMPLEMENTATION	-	+	o	+	+	+	+	+	+
7. LOW LEVEL OF LOCAL NATURAL HAZARD PERCEPTIONS	-	+	-	+	-	+	+	+	+
8. WEAK CONSTITUENCY FOR NATURAL HAZARD POLICY	-	-	+	+	+	+	+	+	+
9. POLICY FAVORS FINANCIAL ASSISTANCE AND AREA PROTECTION WORKS	+	+	-	o	o	+	+	+	+
10. INADEQUATE COORDINATION OF FEDERAL NATURAL HAZARD PROGRAMS	-	+	-	+	-	+	+	+	+
11. LIMITED OPPORTUNITY TO PURCHASE HAZARD INSURANCE	-	-	+	+	+	+	+	+	+
12. LOW PUBLIC INTEREST IN NATURAL HAZARD INSURANCE WHEN AVAILABLE	+	+	-	o	o	+	+	+	+
13. FEDERAL RESEARCH EXPENDITURES NOT MATCHED WITH ANNUAL EXPECTED LOSSES	-	+	-	+	+	+	+	+	+

\+ Policy can assist in problem resolution
o Policy can have no effect on problem resolution
\- Policy can be detrimental to problem resolution

Figure 9-3. Applicability of Public Policy Types to Candidate Public Problems

The Federal Role

Even if agreement can be reached concerning the "problems" which are implicit in natural hazard management, even if agreement can be reached as to which of those problems are "public" in character, and even if agreement can be reached concerning the best mix of policies to deal with those problems, the question then remains: To what level of government falls the primary responsibility for dealing with each problem? What is the role of the federal government in respect to the entire mix of problems and to any specific problem within the set?

Throughout U. S. history, there has been a broad continuing shift in public opinion with respect to the proper role of the federal government within the federal system. In the post-revolutionary period of U.S. history, the checks and balances, the pluralistic federal system of government, and the safeguards against governmental intrusion on personal choice which were built into the national constitution and those of the states were no accident. They were responses to the deep-rooted philosophic, ethical, political, moral, and economic values of society at that time, and a response to the perceptions of that public. That a limited, but very important, role for the federal government was imagined by the framers of those documents and the publics they represented cannot be denied.

Neither, however, can it be denied that later events in United States history recurrently altered the public mood and buttressed arguments in favor of expanding federal roles in respect to many problems. When states and local governments were either unable or unwilling to cope with problems affronting the conscience and problem perspectives of the national public, general willingness to alter the federal role was expressed. Although the general social commitment to "states' rights", "grass-roots government", "pluralism", and "freedom of choice" remained intact throughout social confrontation with the events altering the federal role, there was nevertheless a willingness to get on with the tasks of both a substantively-and a procedurally-democratic society. Frequently, these underlying value orientations - such as "states' rights" - became the slogans of campaigns conducted by stakeholder groups whose interests were less oriented toward the expressed value itself than toward some "selfish" cause that could be served if that value were protected.

This expanding federal role has been the case - through an almost unbroken chain of developments - since the days of the Depression and the presidency of Franklin Delano Roosevelt. Now, however, it appears that a variety of circumstances are leading to a period of public reappraisal of the federal system. In spite of such evident problems as those associated with eroding enviornmental quality, social inequity, inequality of opportunity, consumer abuse, and impediments to the personal pursuit of longevity, security, and self-actualization, there seems to be a growing public disenchantment with the effectiveness and cost of the federal government's current role in public choice-making operations. Although public concern for the problems toward which federal action is directed may be high, it seems reasonable to state that the public is no longer sure that federal domination of the decision-configuring system is the correct or desirable approach to the problem solutions.

Federally-imposed policy and program priorities have obfuscated the agenda of local governments throughout the United States, have produced a wave of local policy-maker involvement in procedural detail rather then the substantive merit of program content, and have frequently produced program mixes and expenditure balances which have been inconsistent with the preferences and priorities of the folks who inhabit the local units of which this nation is constructed. As a result, we may now be entering into a period of growing opposition to an extension of federal action-forcing policies, but on grounds other than those which more typically have motivated the resistance of regulated parties-to-be to oppose such actions in the past. So complex and numerous are the facts and values that surround generally recognized "pulic problems", that many cannot be - and perhaps should not be - resolved at a level which imposes homogeneity upon a people who have been nurtured in the tradition of pluralism. It is, in short, no easy task in the contemporary world to determine "what is right". The answer to this question may require that facts unique to a particular time and place be integrated with the society-consistent but slightly different values which are operative within that situation, in accordance with a calculus in which there is no national agreement.

If we are correct in this non-quantative assessment of a public mood and direction, then the architects of natural hazard management policy may well wish to pointedly consider the question "What is the proper role for the federal government in natural hazards management"?

The raising of this issue is prompted not by any philosophic or political bias on the part of the study team but rather out of a sense that the changing attitudes and moods of the national public will exert powerful constraints on whatever decisions are made concerning the role of the federal government in natural hazards management. Within this context, it may be appropriate to re-examine some old assumptions concerning that role and to reappraise their contemporary validity:

1. State and local communities lack the numbers and quality of human resources to innovate solutions to important problems.

This assumption may well have been correct in the early days of the Republic. For example, the 13 colonies contained only 3.5 million persons when the Constitution was written, and the human resources of the entire nation had to be tapped in order to identify and recruit into government service such talents as those exhibited by Washington, Jefferson, Hamilton, and Madison. Today, however, numerous local communities exceed the total population of the initial 13 colonies. In the contemporary world, few states are so sparsely populated that large reservoirs of outstanding talent cannot be discovered within their borders.

2. State and local communities lack the fiscal resources necessary to deal with such major problems as those posed by natural hazard exposure.

In an earlier period of our history the onset of a major flood was viewed virtually as a "Act of God;" as an unexpected and unpredictable occurrence that could not be planned for, and whose occurrence sometimes signaled a devastating impact upon the economy of the affected area and its component families. Today, we understand that such occurrences can be predicted - if not in terms of the precise hour and exact place of their occurrence - then, at least, in terms of the areas that will be affected with some magnitude of occurrence, at some predictable level of frequency, and within reasonably definable geographic boundary lines. If it was impossible in an earlier era for states and local governments to prepare themselves in advance for such occurrences, this charge can no longer be made. In terms of the individual states in the union, the annual expected building damage and total damage rates presented in Chapter 4 suggests that any state could well establish actuarially-sound reserves of sufficient magnitude to permit it to cope with the consequences of any natural disaster that might occur within its borders. Although it cannot be denied that the build-up of such reserves might involve difficult and unpleasant challenges, including new and continuing cost burdens, neither can it be suggested that states are utterly lacking in the capacity to carry such burdens. In today's world, it may well be that state and local planning of this type is not engaged in for the simple reason that such action is unnecessary; the field has been preempted by the federal government, and it is far easier to rely on that institution and the resources of the entire nation than to tackle one's own problems with one's own resources. One consequence of this, of course, may be a propensity on the part of state and local officials to favor "disaster" declarations for numerous happenings of all types, regardless of whether or not they fit past definitions of truly "disastrous" occurrences.

3. If the federal government doesn't exercise leadership in solving a problem, then the problem will not be solved at all.

The implication of this assumption is that most of the major problems of our time were first identified by the federal government and that the primary means for solving those problems were first invented by that jurisdiction. The facts, of course, are to the contrary! For example, federal intrusions into the field of air quality management were accomplished only after long years of campaigning by western - primarily Californian - legislators, local officials, and community leaders. The broad outlines of the national attack on air quality problems were drafted outside of any federal building and were "sold" to major actors within the federal system. Approaches to problems of the coastal zone were pioneered by one or two states, and the major elements in the nation's attack on urban problems were derived from the pioneering experiences of numerous local units of government. That it may be more convenient for the federal government to draw together the ideas generated by numerous institutions within our society than for any single local or state unit of government to do this job, cannot be denied. However, neither can it be charged that all of the major problems will go unaddressed if the federal government fails to consider them.

However, even if some of our oldest assumptions concerning the need for federal activity are in error, it is also clear that the federal government can undertake some types of activities and handle some problems more effectively, economically, and efficiently than can the individual states or local units of government.

Technology development and transfer programs are illustrative. Fifty natural hazards research institutes in the United States do not appear to be an efficient alternative to a more centralized hazards research operation supervised and/or conducted by such a distinguished central institution as the National Science Foundation. Also, few would deny that the federal government must continue to stand in readiness to act because of the oversight, imprudence, or caprice of state or local policymakers to deal with problems of concern to more than their own constituency. Equal opportunity laws are illustrative here. Thus, it is important to seek the most appropriate balance among governmental jurisdictions for the management of natural hazards and other policies.

One criterion that might be utilized to determine the "federalness" or "localness of a problem is this: to what extent is the problem infused with value questions and value conflicts? The higher the value content, the more numerous the value conflicts between problem-impacted parties, and the more intense the feelings of those parties concerning these questions, then the more "local" is the problem. But its very nature, public policymaking is concerned with reconciling competing claims and value conflicts within a relevant community. The greater the number of value conflicts and the larger the number of value-holding groups, the more difficult is the task of reaching equitable and effective decisions. Localization of decision-making responsibility and authority in theory permits holders of value premises to more directly make their views known to decision makers and— because of the sheer number of local points at which such decisions can be made— permits much pluralism within the system and much opportunity, therefore, for citizens to seek and find a community whose values conform to the taste of the individual seeker.

In short, it appears that the range of information which is necessary for rational decision making - from the objective to the subjective, from the value-free to the value-laden - may well influence the "correctness" of any decision concerning the locus within the federal system at which primary responsibility for decision-making should be assigned. The importance of this general question - where to assign responsibility and authority within the federal system - has been recognized by the Office of Technology Assessment, which has observed - in a recent report - that:

> The federal government has the overall responsibility for conducting the Implementation Plan (for the Earthquake Hazards Reduction Act of 1977) because earthquakes and other natural hazards are national problems. However, when all decisions are made at the federal level, local and state governments tend to adopt a resigned or desperate attitude of "letting George do it," and gradually abdicate responsibility at their own levels. This tension between paternal federal government and maturing local governments must be resolved.

Goal Setting

Policy-maker choices in respect to the resolution of jurisdictional questions, and those relating to the relative importance of problems and problem-solving strategies, are resolved, in part, though policy-maker definition of the purposes and goals that are to comprise the targets of any designed set of public policies.

Accordingly, the following chapter outlines some goals, purposes, and policy actions which seem consistant with the stakeholder interests, decision constraints, loss and cost analyses, and candidate problems which were identified above and in Chapters 4-8.

Chapter Ten

PUBLIC POLICY OPTIONS AND RECOMMENDATIONS

Introduction and Summary

In theory, public policy makers at all levels of government currently face at least three major policy options in respect to the management of natural hazards: (1) adopt no new legislative policies or major administrative policies but continue to implement--as at present--federal, state, and local policy requirements that already have been enacted into law and/or incorporated into administrative regulations and other binding policies, (2) adopt no new public regulatory policies at this time and make no major changes in public distributive policies, but concentrate instead on improving the implementation of existing policies and programs through a focus on natural hazard-related system management, system optimization, attention-focusing, technology development, and technology transfer policies, programs, and operations, or (3) initiate proposals for major changes in current public regulatory and distributive policies in the field of natural hazards management.

This chapter uses the findings contained in the previous nine chapters of this document as a basis for examining the feasibility of these major policy choices and the alternative goals that might serve as the focus for such policy-making. Policy recommendations are presented for each of the three major levels of government and for private organizations and institutions. Also, the chapter relates all policy recommendations to the <u>intrinsic</u> and <u>instrumental</u> public problems to which they are addressed, considers the political and social feasibility of each major set of recommendations, and suggests the future time periods within which action to implement the recommendations appears to be most feasible on the basis of current evidence concerning the social, technical, administrative, political, legal, and economic constraints associated with natural hazards policy-making.

General Policy Options

Option 1: "Do Nothing!"
Continue Current Practices and Policies as They Are

This option appears to be unacceptable for the following reasons:

1. Continued implementation of already-enacted policies in accordance with past administrative and organizational approaches would be inconsistent with current demands being voiced by critical actors within the public policy system and by outside parties. [See the President's Message to Congress, May 23, 1977]

2. As noted in Chapters Four and Five [See Tables 4-1, 4-2, 5-1, and 5-31] a mere continuation of existing policies and administrative-organizational approaches could result in the escalation of total annual expected economic losses from natural hazard exposures in the year 2000 to a level of approximately $17.8 billion. Also, annual expected deaths from natural hazard exposures could increase to a level of 1,790 in that year; and such exposures could yield the loss of approximately 172,000 housing units, 168,300 person-years of homelessness, and more than 200,000 person-years of unemployment in that year.

3. The confusion and uncertainty associated with past and current efforts to implement federal policies would continue, and much imbalance would continue to be exhibited in the distribution of federal resources to technology development, technology transfer, and mitigation activities associated with the several natural hazards.

4. The natural hazard exposure costs to the general body of non-risk-taking taxpayers would continue to increase in magnitude, leading to mounting, and perhaps, imprudent pressures to drastically reduce the magnitude of the federal effort in this field. Alternatively, or perhaps concurrently, the occurrence of a major catastrophe as a result of a high magnitude earthquake or hurricane could stimulate imprudent legislative responses not consistent with the larger needs of the nation and the objective requirements of natural hazard mitigation efforts.

5. "Doing nothing" would be inconsistent with the announced goals of the current administration. Thus, a reorganization of the federal disaster management program was recommended by the President on June 19, 1978, in the form of Reorganization Plan No. 3 of 1978. In submitting the plan, the President suggested that "by consolidating emergency preparedness, mitigation, and response activities it cuts duplicative administrative costs and strengthens our ability to deal effectively with emergencies". The plan establishes the Federal Emergency Management Agency and transfers to that agency the National Fire Prevention and Control Administration and the Federal Insurance Administration, as well as all authorities and functions vested in the President or other federal agencies under the terms of the Disaster Relief Acts of 1970 and 1974, the legislation and orders establishing the Civil Preparedness Agency, and the Federal Preparedness Agency in the General Services Administration. The proposed reorganization would assign to the new agency the oversight responsibilities for the earthquake hazards reduction program being implemented under the terms of PL 95-124 and would vest the agency with responsibility for coordination of federal activities relating to dam safety, natural and nuclear disaster warning systems, assistance to disaster-struck communities, and the development of readiness plans for severe weather-related emergencies including floods, hurricanes, and tornadoes.

The President also announced in the reorganization plan his intention to establish, by executive order, an Emergency Management Committee to be chaired by the new agency director and to consist of the assistants to the President for national security, domestic affairs and policy, and intergovernmental relations, as well as the Director of the Office of Management and Budget. Significantly, the President noted in the proposal his commitment to the view that federal hazard-mitigation activities should be conducted under an organizational structure that permits "more rational decisions on the relative costs and benefits of alternative approaches to disasters". He noted his view that "the focal point of all federal hazards and mitigation activity . . . (will be concentrated in) the Federal Emergency Management Agency".

Thus, it seems clear that a continuation of past policies, approaches, and administrative methods in the field of natural hazards management is unlikely. This policy, therefore, should be viewed as being both infeasible and contrary to the public interest at this time.

Option 2: Initiate "Dramatic New" Initiatives and Changes in Current Policy

If a "do nothing" policy is currently infeasible, so, also, is one that involves immediate and dramatic changes in current basic regulatory, distributive, and action-forcing policy. The current political and social climate of the nation appears to be such that dramatic new federally-initiated approaches to natural hazards management problems would not receive appropriate support by broadly-based political constituencies nor by important policy-makers at any level of government. Convincing evidence is at hand that suggests that community-level opinion leaders and policy-makers do not currently assign a very high priority to natural hazards management activities and that their understanding of the dimensions of natural hazards threats to their communities is far too limited. When this fact is conjoined with the economy-in-government campaigns that are sweeping the nation, with the fact that a sufficiently precise and broad-based pool of data is not yet available to assist in rational and comprehensive natural hazards decision-making at all levels of government, and with the current wave of professional and public concern over the burdens produced by governmental regulatory programs, the overall infeasibility of this policy option seems clear. However, this conclusion is not meant to imply that it would be imprudent in the present to establish the general outlines of possible future major changes in natural hazards management policies and programs. Indeed, near-future activities might well be directed to the development of such outlines and to the establishment of the base of policy-maker understanding and support which is a necessary condition for the adoption and implementation of any substantial new proposals.

Option 3: Concentrate Current Activities on a "Fine Tuning" of the Current System

Given the above observations, it would appear that the most feasible option for the present is to concentrate on design and implementation of changes in system management, system optimization, attention-focusing, technology development, and technology transfer policies and operations to the end that a more effective, efficient, balanced, publicly supported, and internally consistent approach to natural hazard problems may be mounted by the federal and other levels of government.

Candidate Policy Purposes and Goals

As used here, a policy purpose is a very loosely defined end state that establishes the future direction of movement for subsidiary and related decision-making and other activities. A goal, on the other hand, defines the general characteristics of some future state of affairs that is to be achieved and is sufficiently precise so as to permit a neutral analyst to determine the presence or absence of the state. Within the context of these definitions, objectives may be defined as precisely defined states of affairs that are to be achieved at stipulated dates. Objectives typically are definable in quantitative terms, and goals are usually sufficiently precise as to permit further inquiry concerning the quantitative parameters that may be utilized to translate them into more precisely-worded objectives.

Consistent with these definitions, the general purposes of the possible changes that might be considered in current natural hazard management programs are distinguishable in the form of the following goals:

1. Future involuntary exposures to natural hazards should be reduced to an effective level of zero.

One of the oldest and least controversial functions of any government is to protect its citizens from those threats to their health, longevity, safety, and general welfare that are of such a nature that the individual citizen can only imperfectly--if at all--take action to protect himself or herself. Involuntary natural hazard risk-taking borne out of the ignorance of the risk-taker or the inability of the risk-taker to adopt a risk-avoidance strategy, or out of the deliberate withholding of hazard exposure and risk-taking information from the parties who are or might be exposed to the hazard, or out of the organizational and technical disabilities of specific community governments are situations that clearly qualify as targets for governmental activity under this traditional role and responsibility of federal and state governments.

2. Future possible increases in the risk of life loss from natural hazard exposures should be avoided.

On the face of it, this goal is one to which most parties would readily assent. It should be given high priority, but the substantial political and economic questions involved in selection of means for its implementation should be frankly acknowledged. If a real commitment is made to the accomplishment of this goal, then--it is clear--a new level of concern should be given to use of avoidance and other preventive strategies for dealing with life-loss problems.

3. The current and probable future levels of natural hazard costs to non-risk-taking taxpayers should be substantially reduced.

4. Substantial reductions should be made in the level of the projected increase in annual expected losses that are expected to arise from natural hazard exposures in the year 2000.

The projected 1970 to 2000 increase in annual expected natural hazard losses is in excess of the level that was actually tallied in 1970. However important the current level of loss may be that is associated with the exposure of existing populations at risk of loss from hazardous natural occurrences, wisdom suggests the importance of a new and higher level of concern for the projected increases in the sizes of the populations at risk of such exposure.

5. Expanded opportunities should be provided to populations currently at risk of exposure to hazardous natural events to reduce the current level of risk associated with such exposures -- knowledgeably, economically, and in full consideration of relevant costs and benefits.

Accomplishment of this goal is the target of numerous federal, state, and local action programs, including those related to construction of flood control works, disaster relief, disaster warning systems, earthquake prediction, and the strengthening or modification of existing buildings. This goal is worded, however, so as to give clear acknowledgment to the fact that numerous trade-offs are necessary in the processes of decision-making targeted on reduction of the risks incurred by current populations exposed to the conditions within major natural hazard zones. As worded, the goal implies that there may be no single "right" level of risk reduction nor any single "most feasible" strategy to be applied to achieve that risk level.

6. The capacity and readiness of local, state, and federal governmental entities to curb the present and future risks associated with natural hazard exposures should be expanded.

7. The capacity and readiness of individual citizens, groups of citizens, and non-governmental organizations and associations to knowledgeably participate in decision-making activities targeted on determination of the levels of risks and types of mitigation appropriate to deal with natural hazard exposures should be expanded.

Recommendations for Federal Action

Recommendations for federal action are presented in three groups, each conforming to a particular time frame. Phase 1 recommendations are those that are believed to be most feasible for the present to the near future and that provide a foundation for implementation of recommendations intended for later periods. Phase 2 recommendations are those that are intended for implementation in the near to middle range future, while Phase 3 recommendations are those intended for consideration and implementation only after all other recommendations have been appropriately implemented and their outcomes evaluated. In view of the constrained focus of this study, no recommendations are offered in respect to emergency warning systems, earthquake prediction, evacuation plans, relief operations, emergency medical and social services, and post-disaster recovery operations. Neither are the full set of research needs in the field of natural hazard management addressed. Instead, the recommendations are confined to topics that are primarily or necessarily a part of the essential focus of this study: structural losses and mitigations associated with natural hazard exposures.

Phase 1 Recommendations

During the period of the near future, it seems most appropriate that the concerned federal agencies give priority to the development and implementation of improved system management, system optimization, attention-focusing, technology development, and technology transfer policies and programs. Such changes should be designed to correct suspected current substantive, coordinative, and administrative problems associated with the implementation of existing congressional policies and mandates. Although many of the recommendations that are advanced below are related to the responsibilities of the new Federal Emergency Management Agency, others in the set are targeted on "non-catastrophic" losses associated with present and possible future population and building exposures to hazardous natural occurrences.

Recommendation 1. Under the terms of the Disaster Relief Act of 1974 [PL 93-288], Sections 201, 302, 316, 406, and 601, consideration should be given to the issuance of executive orders and/or administrative regulations to accomplish the following:

(a) An integrated, centrally-coordinated, appropriately-budgeted, and appropriately-phased program of hazards zone mapping and classification should be designed and implemented as a joint venture of the several federal agencies responsible for this function under the terms of the Disaster Relief Act of 1974, the Earthquake Hazards Reduction Act, and the various statutes concerned with flood insurance and with the mitigation of flood hazards in coastal and riverine flood plains.

Rationally-conceived hazard management activities are dependent on precise understandings of the metes and bounds of the geographic areas within which specified hazard occurrences of particular intensities and frequencies may be expected. Virtually all groups and researchers who have examined the subject of natural hazard exposures have recommended an expanded, more timely, more comprehensively conceived program of hazard zone mapping on the part of the federal government. Such activities, we believe, should go substantially beyond the mere mapping of the turf upon which a particular hazard, such as damage-producing expansive soils, may be expected to occur. In addition, such activities should include a scheme for classifying hazard zones by type, frequency, and expected intensity or magnitude of hazard occurrences. Thus, in respect to such a well-studied phenomenon as riverine or coastal flooding, this recommendation is meant to suggest that riverine and coastal flood plains should be precisely identified as to their metes and bounds; classified as to the frequency with which flooding is expected in the various sections of the plains (Flood Zones A,B,C,D,E,F); and that each such section should further be classified and coded by height or damage-producing magnitude of the floods expected therein during any flood of a specified frequency.

Thus, such a mapping and classification system would require use of a standard and easily understandable coding system which would be consistent across the range of types of hazard zones.

This recommendation is further intended to suggest that; (1) a priority set of areas should be identified for federal designation as hazard zones; (2) such areas should include zones in which both natural and man-made hazards are expected to occur;(3) the classification and coding system utilized for such zones should be in conformance with technical criteria to be developed through consultation with experts from research, mapping, planning, engineering, and user enterprises and fields; (4) the classification system should extend, where appropriate, to such subjects as the soil characteristics of sub-sections of each hazard zone. Some hazard zones would encompass the whole of existing counties or major sections thereof (as in the case of major wind hazards) while other zones would encompass micro areas internal to single communities (as in the case of 10-year flood return zones of specified magnitudes). Of course, any mapping and classification system which is established should be designed so as to permit identification of parcels of land which fall within more than one type of hazard zone. The classification methods developed through an earlier grant by the National Science Foundation to the Southwest Center for Urban Research (Houston, Texas) may well be adaptable to this purpose.

In view of the loss estimates presented in chapters 4 and 5, priority in establishment of areas to be subject to the proposed system as well as priority for completion of the mapping and classification program should be assigned so as to deal first with: (1) those hazards which exhibit the largest current and projected losses, (2) those areas which are believed to be within hazard zones which are now highly populated or which are expected to receive a substantial number of migrants between 1980 and 2000, and (3) those areas which exhibit the highest annual expected per capita losses of either life or property.

(b) Hazard exposure criteria should be developed for use in association with the hazard zone mapping and classifications system discussed above.

As used here, hazard exposure criteria are defined as predictive or descriptive statements which describe the consequences expected from the exposure of people or property of specified types to specified natural hazards at specified levels of intensity and frequency of occurrence. This definition, therefore, is one which is consistent with the definition of Air Quality Criteria in the Clean Air Act of 1970 as amended.

The recommendation contemplates that such criteria would be quantitative in form, that the use of a variety of expert panels would be necessary to their preparation, and that each criteria statement would be based on empirical evidence or subject to empirical verification. The recommendation further contemplates that the criteria statements would be composed without regard to normative criteria or influences and that they would be composed as statements of probably relationships rather than expressions of what "ought to be."

The process of developing such criteria should serve to resolve many of the issues of fact which now surround the field of natural hazards management and standard setting, and should further serve to identify gaps in our present understanding of the relationships between natural hazard exposures and specified sets of consequences.

(c) Hazard Mitigation Criteria should be developed which specify the reductions in damages or other consequences that may be expected from the application of a specified building or other mitigation to a specified set of objects exposed to a natural hazard.

Hazard mitigation criteria are here defined as statements that predict or describe the reductions in damages or other consequences which may be expected from the application of a specified mitigation to a specified area or class of buildings exposed to a given level and frequency of hazard occurrence under a specified set of geophysical conditions. As in the case of hazard exposure criteria, these statements are viewed as being the product of scientific inquiry, technical panel activities, and empirically defensible information, rather than as statements which reflect political, social, or economic biases.

(d) Cost-feasibility criteria should be developed which express the cost-damage reduction ratios expected from application of a specified hazard mitigation criteria to a set of hazard-exposed objects.

(e) The National Science Foundation should be authorized, funded, and directed to undertake the preparation of such critical literature reviews and the conduct of such research and loss analyses as may be necessary to assure the timely, objective, and effective accomplishment of the above projects in respect to the full range of natural hazards to which the U. S. population is exposed.

Recommendation 2. Hazard zone occupancy and risk analysis studies should be undertaken as the basis for establishment of a national hazard zone model which can be used on a continuing basis to present information concerning the size of the human and building populations which are exposed to the major types of hazards (by frequency and magnitude level).

A comprehensive, balanced, and cost-effective approach to continuing decision-making is necessary to maximize the benefits gained per unit of resources expended on hazards zone research, technology development, and management programs. The proposed national hazards zone model is intended to facilitate the accomplishment of this end by providing, on a near continuous basis, quantitative information concerning the sizes of the populations at risk of exposure to the full range of important natural and man-induced hazards in the numerous hazard zones of the U.S. The recommendation contemplates that: (a) the model would be capable of revealing the sizes of the populations at risk of exposure in such zones, by type, magnitude, and frequency of hazard occurrence; (b) the level of risk associated with such exposures, expressed in terms of annual expected dollar loss, life loss, injury, and morbidity; (c) the model would be capable of expressing the above in respect to populations and/or land areas which are located within more than one type of hazard zone.

We recommend an early identification and review of current federal efforts and information systems which are relevant to this proposal, a critical review of literature bearing on this subject, and the preparation of a more-extended document which would examine the utility, feasibility, and possible cost of such a model.

Recommendation 3. A study should be conducted to determine the capacity of state and local units of government and their professional staffs to engage in the development and implementation of natural hazards management policies and programs, with particular reference to those having implications for building codes, subdivision regulations, housing codes, and land-use planning or zoning standards.

A decade has passed since the report of the National Commission on Urban Problems was developed. With the exception of the study by Field and Rivkin [1975], the recommendations more recently developed by other groups are not generally linked to objective and quantitatively-oriented study findings concerning the current administrative, organizational, and staff capacities of local and state governments. The recommendation assumes the need for such a study and assumes that; (a) such a study would be directed at cities, counties and states exhibiting the highest potential for natural hazard losses;(b) the study would include an examination of plans and programs developed under the terms of the Coastal Zone Management Act, the Disaster Relief Act of 1974, and other similar statutes. It further assumes that such studies would focus on explication of user agency perceptions of the quality, thoroughness, utility, availability, and consistency of current federal regulations, guidelines, technical assistance documents, and other similar materials.

Recommendation 4. A comprehensive study should be undertaken to determine the substantive content and applicability to natural hazards management of: (a) the several model building codes, (b) the several "model" or recommended" state and local hazard-related building, zoning, and subdivision ordinances and state hazards management acts, (c) regulations and standards of federal agencies, and (d) state, county, and local building codes, subdivision regulations, housing codes, and planning ordinances in areas most impacted by potential natural hazard problems.

This recommended study would provide the information base necessary for development of agency and area-specific recommendations concerning possible modifications in natural hazard management policies and structures. The recommendation contemplates that exemplary enactments by local, state, and other bodies would be assembled; that objective criteria would be developed for classifying the sum of the regulations examined; and that the output of the study would be useful for a mix of policy-planning, technical assistance, and staff development purposes.

Recommendation 5. Current federally-sponsored and/or financed training and technical assistance programs and activities in the field of natural hazards management, and in related fields, should be identified, their respective contents and clientele determined, and their compatibility with current and future needs assessed; a comprehensive, well-integrated program of training and technical assistance in support of natural hazard programs at local and state governments thereafter should be developed.

As used here, the terms "training" and "technical assistance" are meant to include training institutes, symposia, newsletters, manuals of instruction, and other materials and services intended to facilitate the conduct of technically-competent activities, operations, and decision-making by personnel of local and state governments.

The recommendation contemplates that activities funded under the terms of the Environmental Education Act, the Intergovernmental Personnel Act, and the statutes relating to natural hazards management and urban or community development would be included within the scope of this recommendation. The suggested study should focus, in part, on identification of possible revisions in the guidelines governing these existing activities so as to increase their utility to the field of natural hazards management.

The recommendation further contemplates that training and technical assistance activities should be targeted on such groups as: (1) elected policy-making officials of local and state governments; (2) technical personnel of land-use planning, regional planning, resource development, building regulation, and subdivision control agencies and organizations.

Recommendation 6. A comprehensive, well-coordinated, and continuing program of public information and education should be conducted so as to acquaint national, state, and local publics and public policy-makers with the essential facts and alternatives concerning natural hazard exposures and their consequences.

It seems clear that responsible and informed future decision-making in the field of natural hazards management will require the active participation of an informed public. Yet, the evidence is overwhelming that even the residents of high hazard areas do not fully comprehend the extent of their risk, the consequences associated with exposures, and the types of adjustments that may be made to mitigate the effects of those exposures. Of course, the design of such a program would require the identification and review of the numerous segmented public information and education efforts in this field that are sponsored by the panoply of federal agencies whose responsibilities impinge in one way or another on the subject of natural hazard exposures.

Some specific possibilities for such a program are as follows:

(a) A "White House" or "National Conference" on Management of Environmental Hazard Zones could be conducted.

When the federal air quality management effort was little more that a loosely-coordinated committee effort within the U.S. Public Health Service, Los Angeles County officials requested President Eisenhower to convene a White House Conference on Air pollution. The resulting series of National Air Pollution Conferences which were conducted by the Department of HEW accomplished several ends: (1) the attention of the national media, influential private associations and organizations, educators and researchers, and policy-makers at all levels of government were drawn to the air pollution problems of the nation, (2) issues and ideas concerning the mitigation of the problems were ventilated before the public eye, and (3) major policy alternatives were identified and examined by a national group of interested parties.

Similar benefits might well result from such an effort in respect to the potential problems posed by continued exposure of people and property to the numerous types of hazard zones within this nation.

(b) Conferences, workshops, and symposia might be conducted for community leaders, influentials, and media representatives of high damage-rate states and counties.

(c) Highly-readable and objective brochures on each of the study hazards could be prepared for distribution to lay publics in areas exhibiting moderate to heavy annual expected losses from exposures to such hazards.

(d) Objective, highly-readable illustrated feature articles on this subject could be prepared for distribution to community (weekly and semi-weekly) newspapers in moderate to high hazard areas.

(e) A series of documentary films could be prepared for broadcast by the Public Broadcasting System and for use by commercial stations.

(f) Under the auspices of a university or some other institution, a series of objective, empirically-defensible, highly-readable hazard-specific "Public Policy Reports" could be prepared for distribution to state and local public policy-makers representing hazard areas in which cost-feasible mitigations can be put to use. As suggested by this study, the prime candidate subjects for such a series of reports are: tsunami, landslide, wind hazards, coastal and riverine flooding.

Recommendation 7. In cooperation with elements of the American insurance industry, a comprehensive, well-budgeted study should be undertaken to (a) determine the possible utility of both comprehensive and categorical hazards insurance systems in the mitigation of the consequences associated with natural hazard exposures, (b) identify the present public policies that constrain the development and extension of such insurance services, (c) review--and possibly develop new--data concerning the factors that influence consumer attitudes toward such insurance, and (d) identify the possible functional and disfunctional consequences associated with legal requirements calling for mandatory purchase of such policies.

In view of the cost-feasibility problems that may be associated with other loss-mitigating strategies in the field of natural hazards management, the potential utility of risk-spreading insurance systems should be determined. Although this subject was not pointedly addressed in the inquiry that resulted in this report, the subject is one whose large importance to natural hazard management programs was suggested by project data outputs. Consideration should be given to a preliminary feasibility study aimed at capturing and assessing existing literature in this field and at identifying information requirements that are perceived to be important by knowledgable members of the insurance industry, insurance regulating enterprises, and natural hazard management authorities.

Recommendation 8. A comprehensive study should be conducted to identify the past, present, and alternative future annual costs of natural hazard exposures which have been or will be externalized to non risk-taking parties.

Recommendation 9. The findings of the study concerning the specific counties in which cost-feasible natural hazard mitigations may be employed should be utilized by federal agencies reviewing coastal zone plans and by those federal officers responsible for the conduct of hearings and the drafting of regulations to implement Section 406 of the Disaster Relief Act, 1974.

Coastal zone management programs already have been approved for two states (Washington and Oregon), approval of two others is expected shortly, and nine others currently are at the point of being submitted [CEQ Annual Report, Dec 1977].

Similarly, the Dept. of HUD recently has announced its intention to conduct public hearings to determine what provisions to include in the regulations to be issued to implement Section 406 of the Disaster Relief Act of 1974.

Phase 2 Recommendations

Following the accomplishment of all or part of the recommendations for Phase 1, it may become technically, politically, and socially feasible to consider the adoption of the following alterations in current federal distributive, regulatory, and action-forcing policies.

Recommendation 1. The federal government should require the sellers, and others involved in the transfer, renting, or leasing of property, to engage in full disclosure of the natural hazard-related risks associated with occupancy of structures and places within hazard zones.

This recommendation contemplates ultimate legislation that would require "full disclosure" on the part of those who sell or offer to sell and of those who offer for rent or lease any parcel of developed or undeveloped property within the United States when such property falls within an area that the federal government has determined to be bounded by a federally-designated hazard zone. The recommendation contemplates that potential purchasers, renters, and lessees of such property be advised by the seller, lessor, or any agents thereof of the nature and classification of the hazard zone within which the property is located, and that this assertion be verified (in the case of property sales) at time of title transfer by the title insuring agency. Although the adoption of a direct federal legislative requirement of this type may exceed the constitutional authority of the federal government, it would appear that adoption of such legislation by state legislatures could well be "forced" by the federal government through federal insistence that the adoption of such legislation be a necessary pre-condition to the establishment of the eligibility of the state, any portion thereof, or any citizen thereof for any benefits under the terms of the Federal Disaster Relief Act of 1974; the Federal Flood Insurance Act, as amended; the various federal flood control acts; and those acts that authorize the activities of such agencies as the Federal Housing Administration and the Federal Home Loan Administration.

In respect to regulations issued under the authority of Federal agencies engaged in morgage transactions, it should be noted that Executive Order 11988 (May 24, 1977) now requires that "agencies which guarantee, approve, regulate, or insure any financial transaction which is related to an area located in a flood plain shall, prior to completing action on such transaction, inform any private parties participating in the transaction of the hazards of locating structures in the flood plain." [Federal Register, Vol. 42, No. 101, May 25, 1977]

Recommendation 2. The federal government should continue to sponsor and fund feasability studies in respect to area flood protection works, should continue to engage in the design of such works, but should alter past policies so as to permit and require the participation of beneficiary parties in the funding of the capital and operating costs associated with such facilities, and so as to prohibit federal participation in any project in which the required benefit-cost relationships can be demonstrated only under conditions of increased flood plain occupancy.

By and large, past federal policies have involved an all-or-nothing approach to the provision of coastal and riverine flood control facilities to communities and states. If such projects were deemed necessary and qualifying under appropriate policies, then the federal government picked up the lion's share of the bills for the project. The recent study of the U.S. Water Resources Council found that only 11% to 20% of the mean, effective, composite cost of rural and urban flood damage reduction facilities and programs, respectively, is being borne by non-federal entities [U.S. Water Resources Council, 1975].

This recommendation contemplates an end to these past policies and assumes that not only the beneficiary states would be partners in the financing of future flood control projects, but the further requirement that precise boundaries be drawn by federal authorities to reveal the land areas and property owners who are the real beneficiaries of risk reductions associated with each flood control project, and that all or a substantial fraction of the capital and operating costs of such facilities be imposed on such land areas and parties. The intent of this recommendation is both to limit past externalization of flood control costs and to provide an opportunity for existing hazard-exposed populations to conveniently exercise the option of mitigating their local risks through use of flood control works, but only under conditions where the project beneficiaries internalize a large fraction of the costs associated with such such flood control activities. Such an amendment of policy could be linked to further requirements intended to prevent future build-ups in flood plain occupancy to levels which might boost total flood-induced costs as a result of enlarged population exposures to greater-than-project flood magnitudes.

In its major thrust, this recommendation is consistent with the spirit and purpose of the several recommendations and declarations advanced by the United States Water Quality Council [Council, 1973; Council, 1976], the U.S. Congress

[P.L. 93-251, Section 80], and the President. In his message to the Congress on May 23, 1977, the President observed that "...it is essential to confine the public works efforts of the water development agencies to projects that can meet such defensible criteria as economic efficiency, safety, environmental protection, and fair distribution of project benefits."

This recommendation contemplates that: (a) the major fraction of the costs associated with construction of area hazard protection works (dams, levees, sea walls, etc.) should be internalized to those who receive the benefits from such expenditures, (b) the construction of such works should be justified in terms of the need to reduce the risks associated with the exposure of existing populations and property to the hazard, and should be so controlled and managed as to prevent unreasonable increases in the sizes of the populations at risk as well as increases in the absolute level of losses resulting from such exposures, and (c) the opportunity for current natural hazard risk-takers who employ this approach to reduce <u>their</u> levels of risk should be preserved, but in a context in which such risk-takers must weigh the costs, benefits, and tradeoffs associated with this approach. The idea that local beneficiaries should share in the costs of federal flood control projects and activities was endorsed by several national groups during the 1975 public hearings conducted by the U.S. Water Resources Council. [The Council, 1975] During those hearings the following positions were taken concerning these matters by spokespersons for the indicated groups:

<u>American Society of Civil Engineers:</u> "Reimbursement and cost-sharing policies should be directed generally to the end that identifiable beneficiaries bear an equitable share of cost commensurate with beneficial effects received in accordance with the project planning objectives."

<u>American Water Resources Association:</u> "The AWRA concurs in general with recommendations for increased non-federal cost sharing. The federal share of financing of water resource programs is often unduly generous, to an extent which results in uneconomic expenditures."

<u>Wildlife Management Institute:</u> "...inadequate cost-sharing policies have promoted unwise development of flood plains and led to overemphasis on ecologically damaging structural solutions to flood problems."

League of Women Voters Education Fund: "...the League has long supported user charges and the general principle that beneficiaries should share in the cost in proportion to benefits received... many projects receive community support because little community investment is required."

Recommendation 3. All federal highways and all other highways which were constructed and/or are maintained in whole or in part with federal funds should be equipped with signs which indicate the points at which those highways transect major natural hazard zones, including - but not limited to - tsunami innundation areas and 100-year, 50-year, 25-year, and 10-year costal and riverine flood plains. Such signs should further indicate, in areas subject to flooding, the flood heights expected at those points during a flood of 100-year frequency.

The purpose of this recommendation is to stimulate the development of improved public understanding of the location of life and property-threatening natural hazard zones and thereby to both reduce involuntary risk taking and to increase the use of risk-reducing adjustments by residents in and users of such zones. In its major thrust, the recommendation is consistent with the spirit of Section 3 (c) of Executive Order 1198 (May 24, 1977), which states, in respect to federal property, as follows:

> "If property used by the general public has suffered flood damage or is located in an identified flood hazard area, the responsible agency shall provide on structures, and other places where appropriate, conspicuous delineation of past and probable flood height in order to enhance public awareness of and knowledge about flood hazards."

Recommendation 4. Building standards enforced by federal lending and mortgage guarantee agencies should be amended so as to require the use of building strengthening mitigations (for wind, flood and earthquake hazards) on new structures in those counties and sub-county areas in which the use of such mitigations has been found to be cost-feasible.

It is the intent of this recommendation that federal lending and mortgage guarantee activities be utilized to foster the use of loss-reducing building strengthening and/or floodproofing/elevating mitigations in those areas and under those conditions where the use of such mitigations is both cost-feasible and contributory to the production of net reductions in the annual expected losses from area natural hazard exposures. This requirement should be extended to expansive soils and other hazard mitigations as rapidly as warranted by available evidence.

Recommendation 5. Federal regulations issued under the terms of Section 406 of the Disaster Relief Act of 1974 should be designed to foster the use of the "highest net savings" mitigations identified in Figure 5-4.

Recommendation 6. Hazard impact and mitigation statements should be required additions to the Environmental Impact Statements currently required in respect to federally-conducted or federally-financed projects.

As used here, the term "hazard impact and mitigation statement" is intended to mean an objectively-prepared statement which: (a) identifies the natural hazard zones or areas in which capital facilities are to be located and/or in which programs are to be conducted, (b) specifies the mitigations which will be employed to reduce the adverse impacts otherwise associated with exposure of project-related persons and properties to the hazards within the area; and (c) identifies the hazard adjustments whose use will be fostered through use of program funds.

It is the intent of this recommendation that such statements be prepared for such critical capital facilities as schools, hospitals, nursing homes, community health centers, and other facilities whose location might well increase the size of the involuntary population at risk of exposure to natural hazards. It is the further intention of this recommendation that such statements be employed to determine the extent to which federally-funded education and other programs have been appropriately adapted to the natural hazard needs of specific areas. Thus, in respect to educational subventions to the states, such statements might well deal with such questions as those relating to the extent to which public school curricula have been designed so as to foster community use of life-saving and injury-avoiding adjustments to such natural hazards as tornadoes, coastal floods, riverine floods, and earthquakes.

Phase 3 Recommendations

In most cases, the recommendations which are advanced for Phase 3 are dependent on prior implementation of the technology development, technology transfer, system-improvement, and loss-reduction recommendations which were recommended for Phase 1 and 2. They assume completion of appropriate assessments of the outcomes associated with implementation of these earlier recommendations. Thus, at this time, one cannot predict with any high level of certainty the extent or significance of the state and local-initiated natural hazard mitigation programs which might well be produced through implementation of the technology development, technology transfer, and attention-focusing recommendations which were advanced above.

Nonetheless, the following possibilities are of sufficient importance that they are offered here as guides for possible Phase 3 action by the federal government.

Recommendation 1. A comprehensive, federally-administered or initiated national program of natural hazards insurance should be designed and implemented.

Should the cost-feasibility findings of this study remain essentially undisturbed after full implementation of Recommendation #1 (Phase 1), then widely-available, affordable, comprehensive natural hazard insurance would have to be viewed as a leading strategy for reducing the potentially-catastrophic personal and familial losses otherwise associated with continuing future exposure of those population subsets which now are at risk of incurring such loss as a result of past locational decisions.

Recommendation 2. The terms of the Federal Disaster Relief Act of 1974 should be altered so as to stimulate and require state and/or local cost-sharing in the post-disaster relief and community rehabilitation services now being funded by the federal government under the terms of that act.

Under present conditions, local politicians, state governors, and other actors within the American policy system face unusual pressures and motivations to declare a wide variety of natural occurrences as "disasters" and thereby to qualify the populations impacted by those events for a variety of federal subsidies and services. At state and local levels, it can be argued that there is little present incentive to abridge appropriately the circumstances under which such declarations are made, nor is there much incentive for state and local communities to build actuarially-sound funds which can be used to deal with the needs posed by future hazardous occurrences within their jurisdictions. The result of this situation has been an apparently mounting federal cost burden for relief and rehabilitation efforts associated with the occurrence of natural disasters.

Recommendation 3. A National Natural Hazard Management Act should be adopted to replace the existing separate enactments dealing with floods, flood insurance, earthquake hazards, and disaster relief-recovery. Such an act should include provisions providing for the implementation of all Phase 1 - 3 recommendations and should further require that: (a) states seeking to qualify for comprehensive natural hazard insurance and other benefits related to disaster relief and recovery be required to meet specified conditions; and (b) the state-qualifying conditions should include a showing that the state has enacted a natural hazards management act which provides for the specification of intra-state natural hazards management zones, for effective use of federally-developed hazard zone mapping and classification information as well as hazard exposure, hazard mitigation, and cost feasibility criteria.

Recommendations for State Action

The following recommendations recognize that: (a) the primary responsibility for the management of natural hazard zones now resides with state and local units of government, (b) much responsible action can be taken by these units through use of information which already is generally available; and (c) the long-term efficacy and cost effectiveness of state/local action will be influenced by the extent to which the recommendations for federal actions are implemented.

Recommendation 1. Coastal states exposed to tsunamis should promptly: (a) identify tsunami inundation areas within their borders, (b) provide for appropriate marking of these areas, and (c) prohibit any new residential development within the boundaries of such zones.

The technical mitigations which have been proposed for tsunami in this study are based on the assumptions that: (a) there are no effective building-strengthening mitigations which may be employed to protect residents of non-engineered dwelling units from the threat of injury and life loss posed by this hazard, and (b) the primary methods for reducing or preventing future injury and life loss from this hazard are those which involve the application of avoidance, hazard warning, and population evacuation systems. The only structures which should be located in such areas as those which meet three tests: (1) they are economically necessary to such places, (2) they cannot be located in other areas, and (3) they are engineered structures.

Recommendation 2. All states abutting the Gulf of Mexico and the Atlantic Ocean should enact legislation and/or take such other action as may be necessary to secure the mapping of coastal flood plains (by frequency and magnitude of expected floods) and the early use of appropriate risk-reducing mitigations within those areas, including; (a) avoidance of all new and replacement construction within the more hazardous of these areas; (b) the avoidance of net new growth in all areas in which there is a moderate or high-risk of property and/or life loss; (c) the use of area protection, building strengthening, and building elevation mitigations for those portions of the flood plains in which low to moderate risks are faced, in which the use of such mitigations are cost-feasible, and in which there is some ascendant need for further development and/or for the protection of existing populations and properties.

Recommendation 3. All states should adopt Natural Hazard Management Acts which require the mapping of natural hazards zones within their boundaries and which require the parties involved in the sale, transfer, renting, or leasing of property to engage in full disclosure of the natural hazard-related risks associated with occupancy of structures and places within natural hazard zones.

In respect to the second portion of this recommendation, some states may wish to consider the enactment of amendments to their business and licensing codes so as to also incorporate the recommended requirement in those codes which govern the conditions under which business or professional licenses may be awarded or periodically re-awarded to persons engaged in the development, sale, transfer, rent, or lease of property.

This recommendation also contemplates that state Natural Hazard Management Acts also should require Departments of Public Instruction to assure that public school curricula include instruction which fosters student understanding of the adjustments which are appropriate to minimize the risks of injury and life loss associated with exposure to the major natural hazards which are endemic to the state.

Recommendation 4. All states should adopt legislation which either imposes minimum and maximum building and housing code requirements on all appropriately-populated local areas, or which requires state-conducted audits and public reports concerning such enactments and the effectiveness of related local enforcement efforts.

Assuming the contemporary correctness of the findings which were offered elsewhere in this report concerning the quality and effectiveness of locally-enacted building and housing codes, and the enforcement programs related thereto, it seems clear that such codes and enforcement activities may well be of uncertain quality in many areas of the nation and inconsistent with local needs for the mitigation of natural hazard risks.

This recommendation assumes that there are three major options which are open to state governments for dealing with this possible problem: (a) ignore the problem: (b) solve the problem by providing for a state-enacted and enforced system of building, housing, and sub-division codes, or (c) take more limited action which preserves local choice over this important subject but which provides maximum assurance that such decisions are based on the current state of related knowledge and are made under conditions where full public participation in the process is assured.

Recommendation 5. All states should adopt or amend state sub-division statutes so as to require that all sub-division applications submitted to any local or state entity must include a hazard impact or mitigation statement, the contents of which must also be provided to all prospective purchasers of such property prior to consummation of title transfer.

This recommendation contemplates that the required "hazard impact and mitigation statements" would conform to the description in Federal Action Recommendation No. 6 (Phase 3). Implementation of this recommendation by state governments would provide an immediate mechanism for dealing with exposure problems that otherwise might arise until that future time when the natural hazard zones of the nation have been fully mapped and appropriately classified. It requires the sub-dividers of property to appropriately examine the major natural hazard features of all potential sub-division sites and to demonstrate that site and construction practices will conform to appropriate hazard-mitigating criteria. The recommendation stops short of suggesting that any specified set of mitigations should be required for sites of particular types, but does contemplate that the information provided in the "impact and mitigation statement" would prompt appropriate regulatory activity by local and state entities charged with responsibility for reviewing and approving such sub-division applications.

Recommendations for Local Units of Government

The following recommendations are intended for implementation by those local units of government whose location, current population size, or anticipated future growth rates suggest the wisdom and feasibility of local action to mitigate the risks associated with natural hazard exposures. At a minimum, such local units of government are defined as including those: located within coastal counties adjacent to major inland lakes, to the two oceans, and to the Gulf of Mexico, subject to riverine, coastal, and other flood problems, located in areas at risk of seismic activity, in which a significant fraction of the land area or population is exposed to expansive soils or landslide hazards, and located in sections of the United States which are particularly vulnerable to wind-induced damage from hurricanes, tornadoes, or other severe wind storms.

Recommendation 1. Each local unit of government should identify the natural hazards to which the human or building populations within its jurisdictions are exposed, the boundaries of the zones within which such exposures take place (natural hazard zones); the magnitude and frequency with which hazardous occurrences are expected within each such zone; and the type and extent of damage, injury, or life loss which is expected within each such zone.

It is the intention of this recommendation that the governing body of each local unit of government should, after receipt of appropriate technical counsel and the conduct of appropriate public hearings, determine the hazardous natural occurrences which are significant enough to the population of that community to warrant public mitigating actions and/or the drawing of natural hazard zones for each such hazard. In those circumstances where such action is deemed appropriate, boundaries would be fixed for natural hazard zones in which such occurrences as expansive soil activity, riverine or coastal flooding, other flooding, earthquake fault activity, landslides, local winds of high velocity, and other similar occurrences are expected.

A wide variety of data currently is available to support local activities of this sort. Thus, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, and the U.S. Soil Conservation Service are now engaged in the identification and mapping of hazardous natural areas, including those susceptible to earthquakes, tsunamis, landslides, volcanic activity, coastal flooding, and riverine flooding. In addition, one or more of these same agencies engage in the preparation and publication of maps and other data concerning local soil characteristics. These may be utilized to assist local jurisdictionsin identifying those areas in which landslide or expansive soil activity may be expected.

Recommendation 2. The master land use plans which have been adopted by local units of government should be modified to include an identification of the natural hazard zones for which boundaries have been drawn as a result of the implementation of the above recommendation.

Recommendation 3. Each local unit of government should prepare and adopt, following appropriate review by local, state, and federal agencies, and following the conduct of appropriate public hearings, a local Natural Hazards Management Plan and Program.

As used here, the term "Natural Hazards Management Plan and Program" is intended to mean a document which: (a) specifies the criteria followed in drawing the boundaries of natural hazard zones; (b) identifies the policies which are to be observed in managing the exposure of people and property to hazard occurrences within such areas; (c) identifies the effects which are expected to be achieved through implementation of the plan; and (d) the residual effects which are expected to continue if all elements of the plan are implemented.

It is intended that such a plan should provide specific technical and policy guidelines to all local agencies and private parties who are engaged in the development and implementation of sub-division regulations, land use plans, building codes, housing codes, activities related to the warning and evacuation of populations from hazardous areas, or in the extension of post-disaster relief and recovery services to such populations.

Recommendation 4. Local sub-division ordinances should be amended so as to require: (a) hazard impact and mitigation statements to be filed with all sub-division applications by applicant parties, (b) prohibit new sub-divisions in high-hazard zones and (c) soils testing, site stabilization, site avoidance, or other site modification activities in specified hazard areas, such as those associated with potential landslide or expansive soils activity.

The suggestion that sub-divisions be prohibited in high-hazard areas is meant to provide a means for implementing the study-identified technical mitigation for landslide, and to provide local units of government with the means for avoidance of new construction in such high-hazard areas as tsunami inundation zones and the high-frequency/magnitude segments of riverine and coastal floodplains.

Recommendation 6. By local ordinance, provision should be made by local governing boards for the mandatory and periodic review of: (a) the natural and other hazards for which zonal boundaries have been set by the jurisdiction; (b) the accuracy of current boundary lines for such jurisdictions; (c) the hazard-mitigating efficacy and cost-feasibility of the jurisdiction's natural hazards management plan or program.

Recommendation 7. Local units of government should review their use of IPA and CETA funds to determine the extent to which those funds now are being appropriately used to meet local natural hazard management requirements.

In many local communities, CETA funds might well be used for such purposes as the removal of particularly vulnerable structures from such high hazard areas as those subject to frequent coastal or riverine flooding. Similarly, CETA personnel could be used to assist low income families in the floodproofing of their properties.

IPA funds may be used by local jurisdictions to send the technical staff of their planning, building, and other hazards management agencies to short-term training institutes concerned with natural hazard management subjects.

Recommendations for Action by Private Entities

The more rapid and effective amelioration of problems posed by natural hazard exposures may be fostered if appropriate private organizations and associations take action to foster improved public and policy-maker understanding of exposure problems and of the major problem-mitigating opportunities. Illustrative of the possibilities are the following recommendations.

Recommendation 1. The American Association for the Advancement of Science should: (a) appoint a multi-disciplinary Commission on Management of Environmental Hazard Zones, and (b) charge the Commission with responsibility for preparation of a report on the subject which is of the scope and quality of the report issues by the AAAS Commission on Air Conservation.

Recommendation 2. An inter-society committee on National Hazard Management Criteria and Research should be sponsored by appropriate national professional societies.

The memberships of a number of professional societies are professionally involved in operations associated with the identification of: (a) natural hazard areas, (b) natural hazard effects, and (c) natural hazard mitigations, costs and consequences. Among such societies are: the American Meteorological Society, the American Society of Civil Engineers, the American Institute of Architects, the American Institute of Planners, the American Public Works Association, the National Association of Insurance Commissioners, the International Conference of Building Officials, and others.

A joint committee representing these several societies could profitably be employed to review the need for, and to develop specific recommendations concerning the several proposals in Recommendation No. 1 for federal government Phase 1 activities. Such a committee could continuously concern itself with identification of the types of criteria needed in the field of natural hazards management and with the type and scope of research necessary to the development of such criteria.

Feasibility and Problem Relevance

The intended problem targets of the several recommendations which were advanced above are depicted in Figure 10-1, while their relationship to the policy taxonomy employed in the study is depicted in Figure 10-2.

Considered as a whole, the recommendations assume that current preference and priority should be given to action which: (a) expands the capacity and readiness of state and local governments to engage in technically-sound and publicly-responsive natural hazard management activities, (b) provides the base of information necessary to accomplish this purpose, (c) builds general public knowledge of and interest in natural hazard exposures and the mitigation of risks associated therewith, (d) expands the need for hazard-exposed populations to fully consider the cost-benefit tradeoffs associated with alternative natural hazard mitigation strategies, and (d) limits the future numbers of individuals who will be exposed to involuntary natural hazard risk-taking. These purposes are listed in descending order of our judgement concerning their current political and social feasibility.

The balance of the recommendations which have been offered (Federal Phases Two and Three, state, local) must be assigned generally lower rankings on the scale of political and social feasibility. Current evidence suggests that: (a) problems other than those associated with natural hazard exposures are currently assigned a much higher priority by policy makers, hazard-exposed populations, and the general public, (b) public and policy maker understanding of natural hazard consequences and mitigation alternatives are at a generally low level, (c) state and local jurisdictions exhibit substantially less than an optimal capacity to engage, at present, in expanded natural hazard management activities, and (d) no easily-identifiable political constituency has yet emerged to sponsor and/or support improved natural hazard management undertakings.

	INTRINSIC PROBLEMS										INSTRUMENTAL PROBLEMS												
	1. INDIVIDUALS RESIDING IN HAZARD ZONES	2. WHOLE COMMUNITIES AT RISK OF LOSS	3. VISITORS INCUR INVOLUNTARY RISK	4. LOSSES EXCEED ANNUAL MITIGATION COSTS	5. REDUCED PROBABILITY OF MORTGAGE PAYOFF	6. PROBLEMS WILL CONTINUE TO INCREASE IN MAGNITUDE	7. COSTS TRANSFERRED TO NON-RISK-TAKING TAXPAYERS	8. POLICIES INCREASE PROPERTY COST	9. POLICIES THREATEN INDIVIDUAL AND COMMUNITY VALUES	10. IMPARIED IMPROVEMENTS IN HUMAN LONGEVITY	1. INADEQUATE PROGRESS IN HAZARD ZONE MAPPING	2. INADEQUATE DATA FOR DEVELOPING MITIGATION CRITERIA	3. INADEQUATE DATA TO ESTABLISH COST-LOSS REDUCTION RATIOS FOR MITIGATION	4. INADEQUATE INFORMATION TO SUPPORT MODEL BUILDING CODE REQUIREMENTS	5. LOCAL BUILDING CODES OF UNCERTAIN QUALITY CAN BE INCOMPATIBLE WITH NATURAL HAZARDS MANAGEMENT	6. LIMITED EFFECTIVE LOCAL PLANNING AND IMPLEMENTATION	7. LOW LEVEL OF LOCAL NATURAL HAZARD PERCEPTIONS	8. WEAK CONSTITUENCY FOR NATURAL HAZARD POLICY	9. POLICY FAVORS FINANCIAL ASSISTANCE AND AREA PROTECTION WORKS	10. INADEQUATE COORDINATION OF FEDERAL NATURAL HAZARD PROGRAMS	11. LIMITED OPPORTUNITY TO PURCHASE HAZARD INSURANCE	12. LOW PUBLIC INTEREST IN NATURAL HAZARD INSURANCE WHEN AVAILABLE	13. FEDERAL RESEARCH EXPENDITURES NOT MATCHED WITH ANNUAL EXPECTED LOSSES
RECOMMENDATIONS FOR FEDERAL ACTION																							
PHASE 1: 1. a) Hazards zone mapping and classification	o	o	o	o	o	o			o	o	o	o	o	o	o	o	o	o		o		o	o
b) Develop hazard exposure criteria	o	o	o	o	o	o			o	o		o	o	o	o	o	o	o		o		o	o
c) Develop hazard mitigation criteria	o	o	o	o	o	o			o	o		o	o	o	o	o	o	o		o			
d) Develop cost-feasibility criteria	o	o	o	o	o	o			o	o		o	o	o	o	o	o	o		o			
e) NSF authorized to accomplish the above	o	o	o	o	o	o			o	o	o	o	o	o	o	o	o	o		o		o	o
2. Establish natural hazard zone model	o	o	o	o	o	o			o	o		o		o		o	o	o					o
3. Study state and local hazards management capacity	o	o	o			o	o		o		o				o	o			o				
4. Determine content and applicability of codes and regulations	o	o	o			o				o				o	o	o			o	o			
5. Develop state and local training programs	o	o	o			o			o	o	o	o	o	o	o	o				o			o
6. Natural hazard public information program	o	o	o	o	o	o		o	o	o					o	o	o	o		o			o
7. Determine feasibility of natural hazard insurance	o	o		o	o	o	o	o	o								o	o	o		o	o	
8. Identify costs externalized to non-risk-takers						o	o	o	o						o			o	o	o	o	o	o
9. Specific measures for high-hazard counties	o	o		o	o	o	o	o	o											o			
PHASE 2: 1. Require full disclosure of natural hazard risks	o	o			o	o	o		o	o								o				o	
2. Require participation of beneficiary parties			o	o		o	o		o						o	o	o	o	o				
3. Highway signs indicating hazard zones	o	o	o														o	o					
4. Require building strengthening where cost-feasible	o	o	o	o	o	o	o			o					o		o	o	o		o		
5. Foster use of "highest not savings" mitigations	o	o		o	o	o				o						o			o	o			
6. Require hazard impact and mitigation statements	o	o	o		o	o			o	o	o	o	o	o	o		o	o	o				
PHASE 3: 1. Implement natural hazards insurance program	o	o		o	o	o	o	o									o	o			o		
2. Require cost sharing of post-disaster relief services						o	o		o							o	o	o				o	
3. Adopt national natural hazards management act	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
RECOMMENDATIONS FOR STATE ACTION																							
1. Protect Tsunami inundation area	o	o	o	o	o	o			o	o									o				
2. Apply mitigations to coastal flood plains	o	o	o	o	o	o			o	o	o	o	o	o	o	o	o		o				
3. Adopt state natural hazard management acts	o	o			o	o	o		o	o								o				o	
4. Building and housing code requirements	o	o	o	o	o	o	o		o	o				o	o	o	o		o		o		
5. Subdivision applications to include hazard impact statement	o			o	o	o	o			o						o	o	o	o			o	
RECOMMENDATIONS FOR LOCAL UNITS OF GOVERNMENT																							
1. Identify natural hazard zones and exposures	o	o															o	o			o		
2. Identify natural hazard zones in master plan	o	o	o			o										o	o						
3. Adopt local natural hzards management program	o	o	o	o	o	o				o					o	o	o						
4. Mitigation policy as part of subdivision ordinances	o				o	o	o			o						o	o				o		
5. Periodic review of hazard zones and management plans	o	o				o																	
6. Identify natural hazard uses of IPA and CETA funds																o							
RECOMMENDATIONS FOR ACTION BY PRIVATE ENTITIES																							
1. AAAS Commission on Management of Environmnetal Hazard Zones	o	o				o					o	o	o	o					o				o
2. Committee on Natural Hazard Management Criteria and Research	o	o				o					o	o	o	o					o				o

Figure 10-1. Intended Candidate Public Problem Targets Natural Hazard Policy Recommendations

	ACTION FORCING	ATTENTION FOCUSING	DISASTER RECOVERY	TECHNOLOGY DEVELOPMENT	TECHNOLOGY TRANSFER	REGULATORY	SYSTEM MANAGEMENT	SYSTEM OPTIMIZATION	INVESTMENT AND COST ALLOCATION
RECOMMENDATION FOR FEDERAL ACTION									
PHASE 1: 1. a) Hazards zone mapping and classification				o	o		o	o	o
b) Develop hazard exposure criteria		o		o					o
c) Develop hazard mitigation criteria				o			o		o
d) Develop cost-feasibility criteria				o					o
e) NSF authorized to accomplish the above				o					o
2. Establish natural hazard zone model				o					o
3. Study state and local hazards management capacity				o	o				o
4. Determine content and applicability of codes and regulations				o					o
5. Develop state and local training programs	o			o	o		o	o	o
6. Natural hazard public information program		o		o	o		o	o	o
7. Determine feasibility of natural hazard insurance							o	o	o
8. Identify costs externalized to non-risk-takers		o	o	o					o
9. Specific measures for high-hazard counties		o	o	o	o				o
PHASE 2: 1. Require full disclosure of natural hazard risks	o	o				o	o	o	
2. Require participation of beneficiary parties	o			o	o	o	o	o	o
3. Highway signs indicating hazard zones	o					o			
4. Require building strengthening where cost-feasible	o			o	o	o	o	o	o
5. Foster use of "highest net savings" mitigations	o			o	o	o	o	o	o
6. Require hazard impact and mitigation statements	o			o	o		o	o	
PHASE 3: 1. Implement natural hazards insurance program	o			o	o	o	o	o	o
2. Require cost sharing of post-disaster relief services	o		o		o	o	o	o	o
3. Adopt national natural hazards management act	o			o	o	o	o	o	o
RECOMMENDATIONS FOR STATE ACTION									
1. Protect tsunami inundation area	o	o		o	o	o	o	o	o
2. Apply mitigations to coastal flood plains	o	o		o	o	o	o	o	o
3. Adopt state natural hazard management acts	o			o	o	o	o	o	o
4. Building and housing code requirements	o			o	o	o	o	o	o
5. Subdivision applications to include hazard impact statement	o			o	o	o	o	o	o
RECOMMENDATIONS FOR LOCAL UNITS OF GOVERNMENT									
1. Identify natural hazard zones and exposures				o			o	o	o
2. Identify natural hazard zones in master plans				o			o	o	o
3. Adopt local natural hazard management program	o			o	o	o	o	o	o
4. Mitigation policy as part of subdivision ordinances	o			o	o	o	o	o	o
5. Periodic review of hazard zones and management plans				o			o	o	o
6. Identify natural hazard uses of IPA and CETA funds		o					o	o	
RECOMMENDATIONS FOR ACTION BY PRIVATE ENTITIES									
1. AAAS Commission on management of environmental hazard zones		o		o	o				o
2. Committee on natural hazard management criteria and research		o		o	o				o

KEY: o Policy can contribute to implementing this action

Figure 10-2. Relationship of Natural Hazard Policy Recommendations to Nine Public Policy Types

REFERENCES

Abernathy, James J. Tornado Protection - Selecting and Designing Safe Areas in Buildings. DCPA Report No. TR 83B. Washington, D.C.:USGPO, 1976.

Advisory Commission on Intergovernmental Relations. Building Codes: A Program for Intergovernmental Reform. Washington, D.C.: 1966.

Alfors, J.T. et. al. Urban Geology - Master Plan for California - Phase 1, A Method for Setting Priorities. Open File Report 72-2, California Division of Mines and Geology, 1971.

Alfors, J.T., J.L. Burnett and T.E. Gay, Jr. Urban Geology - Master Plan for California. Bulletin 198, California Division of Mines and Geology, 1973.

Algermissen, S.T. and David M. Perkins. A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States. U.S. Geological Survey Open File Report 76-416, U.S. Department of the Interior, 1976.

Allen, P. "Foundation Failures in Dallas County." Southern Methodist University unpublished paper, 1974.

Americal Geological Institute. Glossary of Geology. Washington, D.C.: American Geological Institute, 1972.

AIA Research Corporation. Architects and Earthquakes. Washington, D.C.: U.S. Government Printing Office, 1975.

American Insurance Association. National Building Code. New York: the Association, 1976.

American National Standards Institute, Inc. "American National Standards Building Code Requirements for Minimum Design Loads in Buildings and Other Structures." NASI Publication, A58-1-1972. New York, 1972.

American Society of Planning Officials. The Text of a Model Zoning Ordinance, 3rd Edition. Washington D.C.: ASPO, 1966.

Anderson, James E. Public Policy Making. New York: Praeger Publishers, 1975.

Anderson, Robert M. American Law of Zoning, Vol. 1. Rochester, N.Y.: Lawyers Cooperative, 1968.

Armstrong, Joe E. and Willis W. Harmon. Strategies for Conducting Technology Assessments. Department of Engineering - Economic Systems, Stanford University, 1977.

Ayre, R.S. Earthquake and Tsunami Hazards in the United States: A Research Assessment. (NSF-RA-E-75-005) University of Colorado, 1975.

Barnes, S.B. and C. Pinkham. Damage Probability Matrix. Prepared for M.I.T. Cambridge, Mass., 1972.

Bartee, E.M. "A Holistic View of Problem-Solving." Management Science, Vol. 20, No. 4. December 1972, pp 439-447.

Bates, F.L. et al. The Social and Psychological Consequences of a Natural Disaster: A Longitudinal Study of Hurricane Audrey. National Research Council Disaster Study #18. Washington, D.C.: National Academy of Sciences, 1963.

Beyer, Glenn H. Housing and Society. New York: The MacMillan Co., 1968.

Blume, John A. "Civil Structures and Earthquake Safety." Earthquake Conference Proceedings, September 22-24, 1971. Joint Committee on Seismic Safety to the California Legislature, 1971.

Bonilla, M.G. "Surface Faulting and Related Effects." Earthquake Engineering. Ed. R. L. Weigel. Englewood Cliffs, New Jersey: Prentice Hall, 1970.

Bosselman, Fred, David Callies and John Banta. The Taking Issue. U.S. Council of Environmental Quality. Washington, D.C.: U.S. Government Printing Office, 1973.

Brabb, E.E. and F.A. Taylor, U.S. Geological Survey Field Studies Map MF-327 (BDC 37), 1972.

Briggs, R.P., J.S. Pomeroy and W.E. Davies. Landsliding in Allegheny County, Pennsylvania. U.S. Geological Survey Circular 728, 1975.

Broms, Bengt. "Landslides." Foundation Engineering Handbook. Ed. H.F. Winterkorn and Hsai-Jang Fang. New York: Van Nostrand-Reinhold, 1975

Building Cost File. New York: Construction Publishing Company, Inc., 1972.

Building Officials and Code Administrators International, Inc. BOCA Basic Building Code. Chicago, 1975.

Building Research Advisory Board - National Research Council. "Methodology for Delineating Mudslide Hazard Areas." Washington, D.C., 1974.

Buoh, Vincent R. and J.E. Bihr. "Uniform Building Code for Wind Loading." Meeting Preprint 7621. ASCE National Convention, Denver, Colorado, Nov. 1975.

Burton, Ian. Types of Agricultural Occupance of Flood Plains in the United States. Dissertation, Dept. of Geography Research Paper #75. Chicago: University of Chicago, 1962.

Burton, Ian and Robert W. Kates. "The Perception of Natural Hazards in Resource Management." Natural Resource Journal, #3, pp 412-441, 1964.

Burton, Ian, et. al. "The Shores of Megalopolis: Coastal Occupance and Human Adjustment to Flood Hazard." Climatology, Vol. 18, #3. Elmer, New Jersey: C.W. Thortwaite Associates, 1965.

Burton, Ian, Robert W. Kates and Gilbert F. White. The Human Ecology of Extreme Geophysical Events. Natural Hazards Research Working Paper #1. Toronto: University of Toronto Department of Geography, 1968.

California Office of Emergency Services. "California Emergency Plan." 1972.

Carson, W.D. "Estimating Costs and Benefits for Non-structural Flood Control Measures." The Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1975.

Clapp, Charles L. "The Congressman as a Legislator." In Samuel C. Patterson (ed.), American Legislative Behavior: A Reader. Princeton, New Jersey: D. Van Nostrand Company, Inc. 1968.

Coase, R.H. "The Problem of Social Cost." The Journal of Law and Economics, Vol. III, October 1960.

Coates, Joseph F. "The Role of Formal Models in Technology Assessment." Technology Forecasting and Social Change, Vol. 9, 1976.

Cobb, Roger W. and Charles D. Elder. Participation in American Politics: The Dynamics of Agenda Building. Boston: Allyn and Bacon, 1972.

Cochrane, Harold C. Natural Hazards and Their Distributive Effects. Institute of Behavioral Science, University of Colorado, Program on Technology, Environment and Man, Monograph No. NSF-RA-E-75-003, p 58, 1975.

Council on Environmental Quality. Second Annual Report. Washington, D.C.: U.S. Government Printing Office, 1971.

Council on Environmental Quality. Seventh Annual Report. CEQ. Executive Office of the President. Washington, D.C.: USGPO, 1975.

Council on Environmental Quality. Ninth Annual Report. Executive Office of the President. Washington, D.C.: USGPO, 1977.

Culver, Charles, H.S. Lew, G.C. Hart and C.W. Pinkham. Natural Hazard Evaluation of Existing Buildings. Building Science Series 61. Washington, D.C.: U.S. Department of Commerce, 1975.

Dacy, Douglas C. and Howard Kunreuther. The Economics of Natural Disasters, Implications for Federal Policy. New York: The Free Press, 1969.

Davies, Jack. Legislative Law and Process in a Nutshell. St. Paul, MN: West Publishing Company, 1975.

Dewey, John. The Public and Its Problems. Denver: Swallow Publishers, 1954.

Dexter, Lewis Anthony. How Organizations are Represented in Washington. Indianapolis: Bobbs-Merrill, 1969.

Dillon, John Forrest. Commentaries on the Law of Municipal Corporations. 5th Ed. Boston: Little Brown and Co., 1911.

Environmental Science Services Administration. Studies in Seismicity and Earthquake Damage Statistics. Prepared for the Department of Housing and Urban Development, Washington, D.C., 1969.

Federal Register. Vol. 40, No. 214, December 18, 1975.

Federal Register. Vol. 42, No. 101, May 25, 1977.

Field, Charles G. and Steven R. Rivkin. The Building Code Burden. Lexington, Mass: D.C. Heath, 1975.

Fischhoff, B., P. Slovic, S. Lichtenstein, B. Combs and S. Read. "How Safe is Safe Enough? A Psychometric Study of Attitudes Toward Technological Risks and Benefits." Eugene, Oregon: Decision-Research Report 76-9, 1976.

Flawn, P.T. Environmental Geology: Conservation, Land Use Planning and Resource Management. New York: Harper and Row, 1970.

Freund, Ernst. The Police Power, Public Policy and Constitutional Rights. Chicago: Callaghan and Company, 1904.

Friedman, D.G. and T.S. Roy. Simulation of Total Flood Loss Experience of Dwellings on Inland and Coastal Flood Plains. Hartford, Conn.: Travelers Insurance Company, 1966.

Friedman, D.G. The Storm Surge Along the Gulf and South Atlantic Coastlines. Hartford, Conn.: The Travelers Insurance Company, 1971.

Friedman, D.G. and M. Bocaccino. Computer Simulation of the Effects of Adjustments to the Inland Flood Hazard. Hartford, Conn.: The Travelers Insurance Company, 1972.

Fritz, Charles E. "Disaster." In Merton and Nisbet (Eds.) Contemporary Social Problems. New York: Harcourt, 1961.

Fujita, T.T. "Estimate of Areal Probability of Tornadoes from Inflationary Reporting of Their Frequencies." SMRP Research Paper No. 89. Chicago: University of Chicago, Department of Geophysical Sciences, 1970.

Fujita, T.T. "A Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity." SMRP Research Paper No. 91. Chicago: University of Chicago, Department of Geophysical Sciences, 1970.

Fujita, T.T. and A.D. Pearson. "Results of FPP Classification of 1971 and 1972 Tornadoes." Presented at the Eighth Annual Conference on Severe Local Winds. Denver, Colorado, October 1973.

Gilbert, Grove Carl, et al. The San Francisco Earthquake and Fire of April 18, 1906, and their Effects on Structures and Structural Materials. Washington, D.C.: Government Printing Office, 1907.

Golant, Stephen and Ian Burton. "A Semantic Differential Experiment in the Interpretation and Grouping of Environmental Hazards." Geographical Analysis 2, pp 120-134, 1970.

Greenwald, Carol S. Group Power: Lobbying and Public Policy. New York: Praeger, 1977.

Grigg, Neil S. et al. "Urban Drainage and Flood Control Projects: Economic, Legal and Financial Aspects." Colorado State University Completion Report Series No. 65, 1975.

Grigg, Neil S. and O.J. Helweg. "State-of-the-Art of Estimating Flood Damage in Urban Areas." AWRA Water Resources Bulletin, pp 370-390, April 1975.

Grodzins, Morton. The American System: A New View of Government in the United States. Chicago: Rand McNally, 1966.

Grosse, Robert N. "Cost Benefit Analysis of Health Service." Annals of the American Academy of Political and Social Science, Vol. 399, January 1972.

Haas, J. Eugene, Robert W. Kates and Martin J. Bowden. Reconstruction Following Disaster, Cambridge, MA: MIT Press, 1977.

Hagman, Donald G. Public Planning and Control of Urban Land and Development. St. Paul, MN: West Publishing, 1973.

Hagman, Donald and Dean Misczynski. Windfalls for Wipeouts. Chicago: ASPO Press, 1978.

Halstead, Murat. Galveston: The Horrors of a Stricken City. American Publishers' Association, 1900.

Harris, D.L., Characteristics of Hurricane Storm Surge. Technical Paper No. 48. Washington, D.C.: U.S. Weather Bureau, 1963.

Hart, Gary C. Natural Hazards: Tornado, Hurricane, Severe Wind Loss Models. Redondo Beach, CA: J.H. Wiggins Company, 1976.

Hemphill, John A. "Administration as Problem Solving." Edited by Andrew W. Halperin. Administrative Theory in Education. New York: The MacMillan Co., 1967.

Hirschberg, J., P. Gordon and W.J. Petak. "Natural Hazards: Socioeconomic Impact Assessment Model." Redondo Beach, California: J. H. Wiggins Company, 1978.

Ho, F.P., R.W. Schwerdt and H.V. Goodyear. Some Climatological Characteristics of Hurricanes and Tropical Storms, Gulf and East Coast of the United States. Report NWS-15. Washington, D.C.: National Oceanographic and Atmospheric Administration, 1975.

Houston, J.R. and A.W. Garcia. "Type 16 Flood Insurance Study: Tsunami Predictions for Pacific Coastal Communities." U.S. Army Engineer Waterways Experiment Station, Report H-74-3, May 1974.

Houston, J.R. and A.W. Garcia. "Type 16 Flood Insurance Study: Tsunami Predictions for Monterey Bay, San Francisco Bay and Puget Sound." U.S. Army Engineer Waterways Experimental Station, Report H-75-17, November 1975.

Hwang, Li-San and D. Divoky. "Tsunamis." Underwater Journal. October 1971.

Iacopi, Robert. Earthquake Country; How, Why and Where Earthquakes Strike in California. Menlo Park, CA: Lane Books, 1971.

Insurance Information Institute. Insurance Facts 1971. New York, 1971.

International Conference for Building Officials. Uniform Building Code, 1975 Edition. Whittier, California: the Conference, 1976.

Johnson, William K. Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures. Ft. Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, March 1978.

Jones, Charles O. An Introduction to the Study of Public Policy. No. Scituate, MA: Duxbury Press, 1977.

Jones, D.E. and W.G. Holtz. "Expansive Soils, The Hidden Disaster." Civil Engineering. August 1973.

Jones, D. Earl, Jr. "The Expansive Soil Problem." Presented at Symposium on Expansive Soils. Denver, Colorado: Geological Society of America, 1976.

Kash, D.E. Testimony before the U.S. Department of Internal Hearings on Technology Assessment, June 8,9,10,14, 1976. Cited in Strategies for Conducting Technology Assessment by Armstrong and Harmon. Stanford, CA: Stanford University, Department of Engineering - Economic Systems, 1977.

Kates, R.W. "Human Adjustment to Earthquake Hazard." In National Research Council, The Great Alaska Earthquake of 1964, pp 7-31. Washington D.C.: National Academy of Sciences, 1970.

Kates, R.W. "Natural Hazards in Human Ecologic Perspective: Hypotheses and Models." Economic Geography, Vol. 47, pp 438-451, 1971.

Keefe , Wm. J. and Morris S. Ogul. The American Legislative Process. 4th Ed., Englewood Cliffs, New Jersey, Prentice-Hall, 1977.

Krasnowiecki, Jan and Anna Louise Strong. "Compensable Regulations for Open Space." Journal of the American Institute of Planners. 1963.

Krier, James. "Quality Standards for Control of Air Pollution." in Development of Air Quality Standards (A.A. Atkisson and R.S. Gaines, Ed.). Columbus: Charles E. Merrill Publishing Company, 1970.

Kusler, Jon A. and Thomas M. Lee. Regulations for Flood Plains, Chicago: ASPO Press, 1972.

Kusler, J.A. Statutory Land Use Control Enabling Authority for the Fifty States, with special reference to Flood Hazard Regulatory Authority, HUD, Federal Insurance Administration, 1976.

Lee, Larry T., Jon D. Chrostowski and Ronald T. Eguchi. Natural Hazards: Riverine Flooding, Storm Surge, Tsunami Loss Models, Redondo Beach, CA: J. H. Wiggins Company, 1976.

Leslie, S.K. and J.M. Biggs. "Earthquake Code Evaluation and Effects of Seismic Design on the Cost of Buildings." Seismic Design Decision Analysis, Report No. 2, MIT-CE-R72-20. Massachusetts Institute of Technology, May 1972.

Lesso, William G. Potential Wind Damage Reduction Through Use of Wind-Resistant Building Standards. Austin, Texas: Texas Coastal and Marine Council, 1976.

Loftus, Shirley F. "Stocks of Business Inventories in the United States." Survey of Current Business, December 1972.

Los Angeles Times. "Carter Orders Check of High-Hazard Private Dams." Part II, p 8, November 29, 1977.

Lowi, Theodore J. "American Business, Public Policy, Case Studies and Political Theory." World Politics, Vol. 16, pp 677-715, 1964.

Lowrance, William W. Of Acceptable Risk: Science and the Determination of Safety. Los Altos, CA: William Kaufmann, Inc., 1976.

Maldus, J.S. "The Origin of Hurricanes." Scientific American. August 1957.

Mandelker, Daniel R. Managing Our Urban Environment. New York: Bobbs-Merrill Co., Inc., 1966.

Mann, Dean E. "Political Incentives in U.S. Water Policy: Relationships between Distributive and Regulatory Politics." In Matthew Holden, Jr. and Dennis L. Dresang (Eds.) What Government Does. Beverly Hills: Sage, 1975.

Manvel, Allen D. "Trends in the Value of Real Estate and Land, 1956 to 1966." In Three Land Studies. Prepared for the National Commission on Urban Problems, Research Report No. 12. Washington, D.C., 1968.

Mayhew, David R. Congress: The Electoral Connection. New Haven: Yale, 1974.

McClure, Frank E. Performance of Single Family Dwellings in the San Fernando Earthquake of February 9, 1971. Prepared for HUD and NOAA, May 1973.

Michelman, Frank. "Property, Utility and Fairness: Comments on the Ethical Foundations of 'Just Compensation' Law." Harvard Law Review, Vol. 80, 1967.

Mileti, Dennis S., Thomas E. Drabek and Eugene J. Haas. Human Systems in Extreme Environments: A Sociological Perspective. University of Colorado: Institute of Behavioral Science, 1975.

Miller, Crane H. Flood Plain Management; Issues and Alternatives for the Congress. Prepared for the U.S. Office of Technology Assessment, 1978.

Municipal Manpower Commission. Governmental Manpower for Tomorrow's Cities: A Report of the Municipal Manpower Commission. New York: McGraw-Hill, 1962.

Musgrave, John C. "New Estimates of Fixed Non-Residential Business Capital in the United States, 1925-73." Survey of Current Business, pp 23-27. March 1974.

National Commission on Urban Problems. Building the American City. Washington, D.C.: USGPO, 1968.

National Commission on Urban Problems. How the Many Costs of Housing Fit Together: Research Report No. 16. Washington, D.C.: U.S. Government Printing Office, 1969.

National Commission on Urban Problems. Local Land and Building Regulation: Research Report No. 6, Washington, D.C.: U.S. Government Printing Office, 1968.

National Safety Council. Accident Facts 1971. Chicago, 1971.

National Safety Council. Accident Facts 1975. Chicago, 1975.

Office of Emergency Preparedness. Disaster Preparedness: Report to the Congress. Washington, D.C.: Executive Office of the President. January 1972.

Olson, Mancur, Jr. The Logic of Collective Action: Public Goods and the Theory of Groups. New York: Schocken Books. 1971

Ong, John N., Jr. and Arthur Atkisson. "The Nature of Problems and Problem Identifying Concepts and Methods." Problem Analysis and Decision Making. University of Wisconsin, Board of Regents, 1976.

Platt, Rutherford H. "The National Flood Insurance Program, Some Midstream Perspectives." Journal of the American Institute of Planners, Vol. 42, No. 3, pp 303-313. July 1976.

Polenske, Karen R. A Multi-Regional Input-Output Model for the United States. Harvard Economic Research Project, EDA 71-070-6-7-35212, NTIS No. OOM-71-00943. Cambridge, Mass., 1970.

Quarantelli, E.L. and Russell R. Dynes. Images of Disaster Behavior: Myths and Consequences. The Ohio State University: Disaster Research Center, 1973.

Richter, Charles F. Elementary Seismology. New York: W.H. Freeman Press, 1958.

Ripley, Randall B. and Grace A. Franklin. Congress, The Bureaucracy and Public Policy. Homewood, Illinois: Dorsey Press, 1976.

Roder, Wolf. "Attitudes and Knowledge on the Topeka Flood Plain." In G.F. White, (Ed.) Papers on Flood Problems. Department of Geography Research Paper #70, Chicago: University of Chicago, 1961.

Rogers, W.P.et al. Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas. Denver: Colorado Geological Survey, Department of Natural Resources, 1974.

Rossi, Peter, et al. "Are There Long-term Effects of American Natural Disasters?" Journal of Mass Emergencies, forthcoming 1979.

Rowe, William D. An Anatomy of Risk. New York: John Wiley and Sons, 1977.

Russell, Clifford S., David G. Arey and Robert W. Kates. Drought and Water Supply: Implications of the Massachusetts Experience for Municipal Planning. Baltimore: John Hopkins Press, 1970.

Saarinen, Thomas F. Perception of Drought Hazard on the Great Plains. Dept. of Geography Research Paper #106. Chicago: University of Chicago, 1966.

Salisbury, Robert and John Heinz. In Ira Sharkansky, (Ed.) Policy Analysis in Political Science. Chicago: Markham, 1968.

Schattscheneider, E.E. The Semisovereign People. New York: Holt, Rinehart and Winston, 1960.

Schneider, William J. and James E. Goddard. Extent and Development of Urban Flood Plains. Geological Survey Circular 601-J, Washington, D.C.: U.S. Geological Survey, 1974.

Sealy, C.O. "Current Practice of Building Lightly Loaded Structures on Expansive Soils in the Denver Metropolitan Area." In Proceedings of Workshop on Expansive Clays and Shales in Highway Design and Construction. Edited by D.R. Lamb and S.J. Hanna. Washington, D.C.: Federal Highway Administration, Research Division, 1972.

Shavell, Henry. "The Stock of Durable Goods in the Hands of Consumers, 1946-1969." 1970 Proceedings of the Business and Economics Section of the American Statistical Association, pp 241-248, 1971.

Siegan, Bernard H. Other People's Property. Lexington, MA: D.C. Heath, 1976.

Simpson, R.H. and N.B. Lawrence. Atlantic Hurricane Frequencies Along the U.S. Coastline. NOAA Technical Memorandum #NWS SR58. Washington, D.C.: U.S. Department of Commerce, 1971.

Slosson, James E. and James P. Krohn. "Landslide Potential in the United States." California Geology, Vol. 29, No. 10, 1966.

Slosson, J.E. "The Role of Engineering Geology in Urban Planning: The Governor's Conference on Environmental Geology." Colorado Geological Survey Special Publication No. 1, pp 8-15, 1969.

Slosson, James E. "Legislation Related to Earthquakes." California Geology, p 37. February 1975.

Slosson, James E. and James P. Krohn. "Effective Building Codes." California Geology, pp 136-139, June 1977.

Slovic, P., B. Fischhoff and S. Lichtenstein. "Cognitive Processes and Societal Risk Taking." In J.S. Carroll and J.W. Payne, (Eds.) Cognition and Social Behavior. Potomac, Maryland: Lawrence Erlbaum Associates, 1976.

Smith, D.M., P.M. Allen. "A Cost-Benefit Analysis of Housing Foundation Failures." Dallas: Southern Methodist University Department of Economics, 1974.

Solomon, K.A. and D. Okrent. Seismic Building Codes for the City of Los Angeles, California. Brief Case Study. Rand report #P-6018, November 1977.

Southern Building Code Congress International, Inc. Standard Building Code, 1976 Edition. Birmingham, Alabama: The Congress, 1976.

Steinbrugge, Karl V. Earthquake Hazards Reduction: Issues for an Implementation Plan. Working Group on Earthquake Hazards Reduction, Office of Science and Technology Policy, Executive Office of the President, Washington, D.C., 1978.

Steinbrugge, Karl V. et al. San Fernando Earthquake, February 9, 1971. The Pacific Fire Rating Bureau, 1971.

Structural Engineers Association of California (SEAOC). "Report of the Ad Hoc Committee on Cost of Design for Earthquake." San Francisco: O.S.T. Task Force on Earthquake Hazard Reduction. September 1970

Terzaghi, K. "Mechanism of Landslides." In Application of Geology to Engineering Practice. New York: Geologic Society of America, 1950.

Texas Coastal and Marine Council. Hurricane Resultant Building Standards and Natural Hazards. Austin, Texas, 1977.

Texas Coastal and Marine Council. Model Minimum Hurricane Resistant Building Standards for the Texas Gulf Coast. Austin, Texas, 1976.

Thom, H.C.S. "New Distribution of Extreme Winds in the United States." J. Struc. Div. ASCE, Vol. 87, No. ST7, pp 1787-1801, July 1968.

United Nations Office of the U.N. Disaster Relief Coordinator. Guidelines for Disaster Prevention, 3 Volumes. Geneva, 1976.

U.S. Army Corps of Engineers. Cost of Placing Fill in a Flood Plain. The Hydrologic Engineering Center, May 1975.

U.S. Army Corps of Engineers. Final Report of the Chief of Engineers on Civil Works Activities, 1974-5.

U.S. Army Corps of Engineers. Flood Insurance Study, Hilo, Hawaii. Honolulu District, June 1966.

U.S. Army Corps of Engineers. Flood Plain Management Studies, Maps FP-9, -11, -15, -18, -20, -25. Pacific Ocean Division. Prepared in cooperation with the State of Hawaii, 1975.

U.S. Army Corps of Engineers. National Shoreline Study; Shore Protection Guidelines, p 33. Washington, D.C., August 1971

U.S. Army Corps of Engineers. Report on Hurricane Camille, August 14-22, 1969. Mobile, Alabama: U.S. Army Engineer District, 1969.

U.S. Bureau of the Census. Census of Housing: 1970 Detailed Housing Characteristics, Final Report HC (1)-B1. U.S. Summary. Washington, D.C.: U.S.G.P.O, 1972.

U.S. Bureau of the Census. County and City Data Book, 1972. Washington, D.C.: U.S.G.P.O., 1973.

U.S. Bureau of the Census. Current Population Reports. Series P-25, No. 470. "Projections of the United States, by Age and Sex: 1970 to 2020." Washington, D.C.: U.S.G.P.O., 1971.

U.S. Bureau of the Census. Statistical Abstract of the United States: 1972. (93rd Edition) Washington, D.C.: U.S.G.P.O., 1972.

U.S. Bureau of the Census. Statistical Abstract of the United States: 1975. Washington, D.C.: U.S.G.P.O., 1975

U.S. Bureau of Economic Analysis. Fixed Non-Residential Business Capital in the United States, 1923-1973. Washington, D.C.: U.S.G.P.O., 1974.

U.S. Bureau of Economic Analysis. "The Input-Output Structure of the United States Economy: 1967." Survey of Current Business. Washington, D.C.: U.S.G.P.O., 1974.

U.S. Bureau of Economic Analysis. The National Income and Product Accounts of the United States, 1929-1965, Statistical Tables. Supplement to the Survey of Current Business, 1967.

U.S. Bureau of Economic Analysis. "Revised Deflators for New Construction, 1947-1973." Survey of Current Business, August 1974.

U.S. Bureau of Economic Analysis. Summary Input-Output Tables of the U.S. Economy: 1968, 1969, 1970. Staff Paper No. 27. Washington, D.C.: U.S.G.P.O., 1975.

U.S. Congress. Insurance and Other Programs for Financial Assistance to Flood Victims. 89th Congress, Print No. 43. Committee on Public Works, 1966.

U.S. Congress. Technology Assessment in Business and Government. Joint Office of Technology Assessment. Washington, D.C.: U.S.G.P.O., 1977.

U.S. Congress. Senate Committee on Banking and Currency. Insurance and Other Programs for Assistance to Flood Victims. Department of Housing and Urban Development Report, Washington, D.C., 1966.

U.S. Congress. Senate Committee on Banking, Housing and Urban Affairs. Oversight on Federal Flood Insurance Programs. 94th Congress, 1st Session, 1975.

U.S. Department of Agriculture, Soil Conservation Service. Guide for Interpreting Engineering Uses of Soils. Washington, D.C., 1971

U.S. Department of Commerce, Environmental Science Services Administration, "Severe Local Storm Occurrences, 1955-1967." M.E. Pautz, ESSA Memo WBTM FCST 12, Sept. 1969.

U.S. Department of Commerce. Highlights of the National Household Fire Survey. Washington, D.C., 1976.

U.S. Department of Commerce. An Inquiry into the Long-Term Economic Impact of Natural Disasters in the United States. Prepared by Harbridge House, Inc. for Office of Technical Assistance, Economic Development Administration, 1972.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Natural Hazard Management in Coastal Areas, 1976.

U.S. Department of Housing and Urban Development, Federal Insurance Administration. Elevated Residential Structures - Reducing Flood Damage Through Building Design: A Guide Manual. Washington, D.C., 1976.

U.S. Department of Urban Development, Federal Housing Administration. Minimum Property Standards for One and Two Living Units. Report Number 300, Washington, D.C., 1966.

U.S. Office of Emergency Preparedness, Executive Office of the President. Disaster Preparedness. Washington, D.C.: U.S.G.P.O., 1972.

U.S. Water Resources Council. OBERS Projections, Regional Economic Activity in the United States, Series E, Populations, Vols. 1-7. Washington, D.C.: U.S.G.P.O., 1974.

U.S. Water Resources Council. Options for Cost Sharing. Part 5A, Table 5A-1, Washington, D.C., 1975.

U.S. Water Resources Council. Planning and Cost Sharing Policy Options for Water and Related Land Programs, Supplementary Information. Part 8C. Washington, D.C., 1975.

U.S. Water Resources Council. Principles and Standards for Planning Water and Related Land Resources. Washington, D.C., 1973.

U.S. Water Resources Council. A Unified National Program for Flood Plain Management. Washington, D.C., 1976.

Valley, S.L. Handbook of Geophysics and Space Environments. New York: McGraw-Hill, 1965.

Vogler, David J. The Politics of Congress. 2nd Edition, Boston: Allyn and Bacon, 1977.

Weigel, R.L. (Ed.) "Tsunamis", in Earthquake Engineering. Englewood, NJ: Prentice Hall, 1970.

White, Gilbert F. and Eugene J. Haas. Assessment of Research on Natural Hazards. Cambridge, Mass: The MIT Press, 1975.

White, Gilbert F. et al. Changes in Urban Occupance of Flood Plains in the United States. Department of Geography Research Paper #57. Chicago: University of Chicago, 1958.

White, Gilbert F. Choice of Adjustment to Floods. Department of Geography Research Paper #93. Chicago: University of Chicago, 1964.

White, Gilbert F. "Flood Hazard in the United States: A Research Assessment." University of Colorado Monograph NSF-RA-E-006. 1975.

White, Gilbert F. Natural Hazard Management in Coastal Areas. Prepared for the U.S. Department of Commerce, Office of Coastal Zone Management, 1976.

White, Gilbert F. (Ed.) Natural Hazards: Local, National, Global. New York: Oxford University Press, 1974.

Whitman, R.V., S.T. Hange and J.W. Reed. Damage Statistics for High Rise Buildings in the Vicinity of the San Fernando Earthquake. School of Engineering, Massachusetts Institute of Technology, Apr. 1973.

Whitman, Robert V. et al. "Methodology and Pilot Application." Seismic Design Decision Analysis Report No. 10, Department of Civil Engineering, Massachusetts Institute of Technology, 1974.

Wiggins, J.H., J. Hirschberg and A. Bronowicki. "Budget Justification for Earthquake Engineering Research." Redondo Beach, California: J.H. Wiggins Co., 1974.

Wiggins, J.H., J. Slosson and J. Krohn. "Earthborne Hazard Analysis, An Expected Loss Assessment of Earthquake, Landslide, Expansive Soil." Redondo Beach, CA: J.H. Wiggins Company, 1976.

Wiggins, J.H., J.E. Slosson and J. Krohn. "Natural Hazards: Earthquake, Landslide, Expansive Soils Loss Models." Redondo Beach, CA: J.H. Wiggins Co., 1978.

Williams, Lawrence A., Eddie M. Young and Michael A. Fischetti. Survey of the Administration of Construction Codes in Selected Metropolitan Areas. A report prepared for the National Commission on Urban Problems, Springfield, VA., Clearinghouse for Scientific and Technical Information, 1968.

Winterkorn, H.F. "Soil Stabilization." In Foundation Engineering Handbook. Edited by Winterkorn, J.F. and Hsai-Yang Fang. New York: Van Nostrand-Reinhold, 1975.

World Almanac and Book of Facts. New York: Newspaper Enterprise Association, 1978.

Wright, Richard, Samuel Kramer and Charles Culver (Eds.) Building Practices for Disaster Mitigation (National Bureau of Standards Building Series 46). Washington, D.C.: U.S. Government Printing Office, 1973.

Young, Allan H. et al. "Residential Capital in the United States, 1925-70." Survey of Current Business, pp 16-27. November 1971.