Multihazard Mitigation Council

MMC

A public/private partnership designed to reduce the economic & social costs of natural hazards

the MMC is a council of the
National Institute of Building Sciences

NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities

Volume 2 − Study Documentation

THE MULTIHAZARD MITIGATION COUNCIL

The *Multihazard Mitigation Council (MMC)*, a council of the National Institute of Building Sciences (NIBS), was established in November 1997 to reduce the total losses associated with natural and other hazards by fostering and promoting consistent and improved multihazard risk mitigation strategies, guidelines, practices, and related efforts. The scope of the Council's interests is diverse and reflects the concerns and responsibilities of all those public and private sector entities involved with building and nonbuilding structure and lifeline facility research, planning, design, construction, regulation, management, and utilization/operation and the hazards that affect them. In recognition of this diversity, the Council believes that appropriate multihazard risk reduction measures and initiatives should be adopted by existing organizations and institutions and incorporated into their legislation, regulations, practices, rules, relief procedures, and loan and insurance requirements whenever possible so that these measures and initiatives become part of established activities rather than being superimposed as separate and additional. Further, the Council's activities are structured to provide for explicit consideration and assessment of the social, technical, administrative, political, legal, and economic implications of its deliberations and recommendations. To achieve its purpose, the Council conducts activities and provides the leadership needed to:

♦ Improve communication, coordination, and cooperation among all entities involved with mitigation;

♦ Promote deliberate consideration of multihazard risk reduction in all efforts that affect the planning, siting, design, construction, and operation of the buildings and lifelines systems that comprise the built environment; and

♦ Serve as a focal point for the dissemination of credible information and sage counsel on major policy issues involving multihazard risk mitigation.

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*The Multihazard Mitigation Council,
a council of the National Institute of
Building Sciences*

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In Memoriam

The Multihazard Mitigation Council wishes to acknowledge James M. Delahay, PE, for his contributions to the Applied Technology Council's research/analysis efforts and his significant contributions to the profession of structural engineering and the nation's codes and standards development efforts. The built environment and all those who use it have benefited tremendously from his work.

PREFACE

The National Institute of Building Sciences through its Multihazard Mitigation Council is pleased to submit this report to the Congress of the United States on behalf of Federal Emergency Management Agency (FEMA) and the Department of Homeland Security. This report presents the results of an independent study to assess the future savings from hazard mitigation activities.

This study shows that money spent on reducing the risk of natural hazards is a sound investment. On average, a dollar spent by FEMA on hazard mitigation (actions to reduce disaster losses) saves the nation about $4 in future benefits. In addition, FEMA grants to mitigate the effects of floods, hurricanes, tornados, and earthquakes between 1993 and 2003 are expected to save more than 220 lives and prevent almost 4,700 injuries over approximately 50 years. Hurricane Katrina painfully demonstrates the extent to which catastrophic damage affects all Americans and the federal treasury.

The MMC Board wishes to acknowledge the efforts of its subcontractor, the Applied Technology Council (ATC). Further, it applauds the innovative and painstaking work of the ATC research team under the guidance of Ronald T. Eguchi of ImageCat, Inc., the project technical director. The team members were: Adam Z. Rose of The Pennsylvania State University, leader of the benefit-cost analysis portion of the study; Keith Porter, Consultant, co-leader of that portion of the study; Elliott Mittler, Consultant, leader of the community research portion of the study; Craig Taylor of Natural Hazards Management Inc., co-leader of that portion of the study; Corey Barber of the University of California, Berkeley; Jawhar Bouabid of PBS&J; Linda B. Bourque of the University of California, Los Angeles; Stephanie Chang of the University of British Columbia; Nicole Dash of the University of North Texas; James Delahay of LBYD, Inc.; Charles Huyck, ImageCat, Inc.; Christopher Jones, Consultant; Megumi Kano of the University of California, Los Angeles; Karl Kappler of the University of California, Berkeley; Lukki Lam of the University of California, Berkeley; Rebecca C. Quinn, CFM, RCQuinn Consulting, Inc.; Archana More Sharma of the University of California, Los Angeles; Kenneth Strzepek of the University of Colorado; John Whitehead of Appalachian State University; Michele M. Wood of the University of California, Los Angeles; Kathryn Woodell of the University of California, Berkeley; and Bo Yang of The Pennsylvania State University. Thanks also go to the ATC Independent Project Review Team members William Petak of the University of Southern California, David Brookshire of the University of New Mexico, Stephanie King of Weidlinger Associates, Inc., Dennis Mileti of the University of Colorado, Doug Plasencia of AMEC Earth and Environmental, and Zan Turner of the City and County of San Francisco; to the ATC project staff including Thomas R. McLane and Christopher Rojahn; and to additional consultants engaged by ATC (James R. McDonald of McDonald-Mehta Engineers, Bruce Miya, and Douglass Shaw of Texas A&M University).

The MMC also offers its thanks to the Project Management Committee established to oversee the project on its behalf. The committee members have spent countless voluntary hours reviewing study materials and providing guidance to the MMC subcontractor conducting the data analysis effort, and the MMC Board thanks them very much for their extraordinary contribution of time

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EXECUTIVE SUMMARY

The Federal Emergency Management Agency (FEMA) asked the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) to conduct an independent study to quantify the future savings from hazard mitigation efforts. The study examined mitigation activities related to earthquake, wind, and flood funded through three major FEMA natural hazard mitigation grant programs (the Hazard Mitigation Grant Program, Project Impact, and the Flood Mitigation Assistance Program).[1] Study results indicate that the natural hazard mitigation activities funded by the three FEMA grant programs between 1993 and 2003:

- Were cost-effective and reduced future losses from earthquake, wind, and flood events;

- Resulted in significant net benefits to society as a whole (individuals, states, and communities) in terms of future reduced losses; and

- Provided significant potential savings to the federal treasury in terms of future increased tax revenues and reduced hazard-related expenditures.

This study involved two interrelated components. The first component, a benefit-cost analysis of FEMA mitigation grants, estimated the future savings from FEMA expenditures on mitigation activities. This component was quantitative and considered a statistical sample of FEMA-funded mitigation activities selected from the National Emergency Management Information System (NEMIS) database. The unit of analysis for this component was the individual FEMA-funded grant. The second study component, community studies, assessed the future savings from mitigation activities through empirical research on FEMA-funded mitigation activities carried out in community contexts. The community studies were both quantitative and qualitative and examined mitigation activities in a purposive sample of communities. The community studies examined all FEMA mitigation grants received by the selected communities since the programs began in 1988. It provided insights into mitigation effectiveness by exploring how mitigation activities percolate throughout the community in the form of synergistic activities — mitigation efforts that would not have occurred had it not been for the original FEMA grant. The unit of analysis was the individual community.

Both components employed common methodologies to the extent possible. In general, a broader range of benefits (especially with respect to the environment and historic structures) were considered in analyzing the FEMA mitigation grants than in the community studies. The study data collection and analysis activities were conducted for the MMC by an Applied Technology Council (ATC) research team of more than 30 experts in a variety of disciplines (see Appendix A for a list of ATC research team members).

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[1] The Hazard Mitigation Grant Program, which assists states and communities in implementing long-term hazard mitigation measures following presidentially declared disasters; Project Impact, which supported pre-disaster mitigation programs; and the Flood Mitigation Assistance Program, which funds state and community measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the National Flood Insurance Program.

Chapter 1
INTRODUCTION

"An ounce of prevention is worth a pound of cure."

Natural hazards such as floods, hurricanes, tornadoes, and earthquakes can cause billions of dollars in damage when they happen. Much of the expense of this societal loss is borne by the federal government. But does "an ounce of prevention is worth a pound of cure" hold true when the federal government invests in natural hazard mitigation with the objective of reducing or eliminating losses from future natural disasters? To answer this question, the Senate Appropriations Committee, Subcommittee for the Veterans Administration, Department of Housing and Urban Development, and Independent Agencies of the 106th Congress mandated this study (Senate Report 106-161) stating:

> The Committee recognizes that investing in mitigation will yield reductions in future disaster losses, and that mitigation should be strongly promoted. However, an analytical assessment is needed to support the degree to which mitigation activities will result in future "savings." Therefore, the Committee directs FEMA to fund an independent study to assess the future savings from the various types of mitigation activities.

This document, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, *Volume 2 – Supporting Documentation*, describes how the analytical assessment was performed, documents the methods used, and explains the results. Volume 1, Findings, Conclusions, and Recommendations, presents the MMC Board's synthesis of the study results.

1.1 Purpose and Background

The Federal Emergency Management Agency (FEMA) charged the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) with conduct of the mandated study. The MMC explored possible approaches and issued a report presenting the parameters for the independent assessment (MMC, 2002).

The parameters report called for:

> Two interrelated studies on representative mitigation activities and communities to allow nationwide generalizations regarding future savings from mitigation. One study will involve empirical research on the savings realized through the application of specific mitigation activities in varying risk contexts and will use a nationwide statistically representative sample of commonly used mitigation activities. The other study will involve empirical research on savings realized through mitigation activities carried out in specific community contexts and will use a sample of communities selected deliberately and in a systematic way that will maximize variations in hazards and mitigation measures considered.

In conducting the study, the MMC first issued a request for qualifications, received five responses, requested full proposals from two organizations deemed to have the best

qualifications, and selected the research team organized by the Applied Technology Council to perform the research and analysis work needed for the independent assessment, the results of which are presented in this report. The research team included more than 30 experts in diverse fields including structural engineering, hazard loss estimation, regional economics, environmental economics, geographical information systems, sociology, health, and public policy (Appendix A).

1.2 Federal Mitigation Grant Programs

The Federal Emergency Management Agency (FEMA), the lead agency in providing federal disaster relief, has made natural hazard risk mitigation a primary goal in its efforts to reduce the long-term cost of disasters. During the period studied, FEMA conducted three programs in support of this goal: the post-disaster Hazard Mitigation Grant Program (HMGP) and two pre-disaster programs, Project Impact (PI) and the Flood Mitigation Assistance (FMA) Program. The Hazard Mitigation Grant Program, the oldest and largest of the three programs, was created in 1988 to assist states and communities in implementing long-term hazard mitigation measures following presidentially declared disasters. Between 1993 and 2003, FEMA obligated $3.5 billion for states and communities to invest in a variety of eligible mitigation activities selected as the most beneficial by local officials.

Project Impact was a program funded between fiscal years 1997 and 2001. Unlike the Hazard Mitigation Grant Program, which provides funding after disasters, Project Impact supported the development of pre-disaster mitigation programs. In total, 250 communities in every state and some U.S. territories received $77 million in grants ranging from $60,000 to $1,000,000 per community. The one-time Project Impact grants were considered seed money for building disaster-resistant communities and encouraged government to work in partnership with individuals, businesses, and private and nonprofit organizations to reduce the impact of likely future natural disasters.

The Flood Mitigation Assistance Program was created as part of the *National Flood Insurance Reform Act of 1994* with the specific purpose of reducing or eliminating claims under the National Flood Insurance Program (NFIP). The Flood Mitigation Assistance Program provides funding to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the National Flood Insurance Program. Annual funding of $20 million from the National Flood Insurance Fund is allocated to states that, in turn, obligate it to communities. Like Project Impact, the Flood Mitigation Assistance Program supports pre-disaster mitigation.

Note that the present study does not estimate the benefits of all FEMA mitigation grant expenditures during the study period. Approximately $200 million in grants were not addressed for any of several reasons but primarily because they did not address one of the three hazards (earthquake, flood, and wind) examined in this study.

1.3 Study Objectives

The objective of the independent study was to quantify the expected benefits of avoided hazard-induced losses and the potential future savings for the three FEMA hazard mitigation programs described above. The study consisted of two major components.

The first component, a benefit-cost analysis of FEMA mitigation grants, estimated the future savings from FEMA mitigation activities based on past FEMA mitigation expenditures. This study component is quantitative and was performed on a statistical sample of FEMA-funded mitigation activities selected from the National Emergency Management Information System (NEMIS) database. The unit of analysis for the benefit-cost analysis of FEMA mitigation grants is the individual FEMA-funded grant.

The second study component, community studies, assessed the future value of mitigation activities through empirical research conducted on savings realized through mitigation activities carried out in community contexts. This study component is both quantitative and qualitative and examines mitigation activities previously funded by FEMA in a purposive sample of communities. The purposive selection procedure considered criteria such as hazard and community size and included a blind draw ─ in other words, communities were not "cherry-picked" or selected because of their mitigation reputation or any other special characteristic. The unit of analysis in the community studies is the individual community.

1.3.1 Benefit-Cost Analysis of FEMA Mitigation Grants

In the benefit-cost analysis of past FEMA mitigation grants, a variety of methods was used to estimate the benefits of a sample of past FEMA-funded grants. Grants for different types of mitigation activities (project and process) and hazards (earthquake, wind, and flood) were selected. This estimate was developed using established principles of benefit-cost analysis as codified by several federal government agencies. These principles were applied to several categories of avoided losses (benefits): property damage, business interruption, casualties, negative societal and environmental impacts, and destruction of historic buildings. These losses were measured in terms of real resources lost to the nation as a whole. The analysis of FEMA mitigation grants also evaluated how various federal tax revenues and transfer payments could potentially be affected by hazard mitigation. The analysis of FEMA mitigation grants was structured to answer three questions:

1. What are the net benefits of hazard mitigation to the nation?
2. Do these benefits vary across types of hazards and mitigation activities?
3. What are the potential savings to the federal treasury from hazard mitigation?

1.3.2 Community Studies

The community studies component assessed the broad benefits from FEMA mitigation activities using empirically collected data from eight purposively selected communities. In addition to FEMA-funded activities, the community studies investigated mitigation activities funded by non-FEMA federal and state agencies that were either associated with and/or independent of FEMA-funded activities. The purpose of this wide focus was to determine the context within which

community hazard mitigation occurs. The community studies investigation was structured to answer the following questions:

1. What is the magnitude of the ratio of the benefits to costs of hazard mitigation activities funded by FEMA when evaluated within a community context?

2. What, if any, additional mitigation activities and benefits were stimulated by FEMA Hazard Mitigation Grant Program, Project Impact, and Flood Mitigation Assistance Program activities?

1.3.3 Types of Mitigation Activities

The study addresses two applications of grant funding referred to herein as project and process mitigation activities. Project activities include physical measures to avoid or reduce damage resulting from disasters. Typically they involve acquiring, elevating, or relocating buildings, lifelines or other structures threatened by floods; strengthening buildings and lifelines to resist earthquake or wind forces; and improving drainage and land conditions (MMC, 2002). Process activities lead to policies, practices, and other activities that reduce risk. These efforts typically focus on assessing hazards, vulnerability, and risk; conducting planning to identify mitigation efforts, policies, and practices and set priorities; educating decision-makers and building constituencies; and facilitating the selection, design, funding, and construction of projects (MMC, 2002).

1.4 Study Characteristics

This study was conducted independent of FEMA. Its assumptions were generally conservative ─ that is, where uncertainty was high, the parameters and methods chosen were those that produced lower estimates of benefits. Sensitivity analyses were conducted on key variables to determine whether the results are robust. The Multihazard Mitigation Council will maintain all data collected from FEMA regional offices and from FEMA databases for use by researchers who wish to test the results, in accordance with the confidentiality requirements of the Office of Management and Budget's Circular A-130 and the Institutional Review Board at the University of California at Los Angeles.

Independent review of this study was provided by the periodic review and input of an Internal Project Review Team (IPRT), six nationally recognized experts providing independent, broad, consensus-based input to the research team. (A letter of endorsement from the IPRT is included in Appendix A of this report.)

1.5 Organization of Report

This volume, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities, Part 2 – Supporting Documentation*, is organized into seven chapters, including this introduction, plus a series of appendices.

Chapter 2, Principles and Definitions, provides a discussion of guiding principles of this study, an overview of key methodologies that define its scope and depth, and important definitions and

delineations. The discussion lays the foundation for more detailed and complex summaries of the approach this study took to assess the benefits and costs of mitigation activities.

Chapter 3, Data Collection, Processing, and Analysis, introduces the primary datasets for both the benefit-cost analysis of FEMA mitigation grants and the community studies. These datasets are used to establish the costs of all FEMA mitigation activities, to help select the stratified sample for the benefit-cost analysis of FEMA mitigation grants and the communities evaluated in the community studies analysis, and to help support comparative analysis studies of community mitigation.

Chapter 4, Methodology, is critical to understanding the underlying methods used for both the benefit-cost analysis of FEMA mitigation grants and the community studies. In many cases, common methods are employed in both parts of the study, and HAZUS®MH (a loss estimation software) was used when possible. Estimating expected losses, impacts to buildings and infrastructure, and exposed populations from earthquake and hurricane wind used common methodologies. In some cases, the benefit-cost analysis of FEMA mitigation grants involved a more in-depth analysis of benefits by examining a wider range of impacts, especially to the environment and historic structures. At the same time, the community studies offered additional insights into mitigation effectiveness by exploring how FEMA-funded mitigation activities percolate throughout the community in the form of synergistic activities that would not have occurred had it not been for the original FEMA grant.

Chapter 5, Community Studies, contains the results of the community analysis. In total, eight communities were investigated based on the combination of FEMA-funded grants received since the start of the Hazard Mitigation Grant Program in 1988 (e.g., multiple hazard exposure), the hazard levels experienced, size of FEMA-funded grants, population of the community, and the FEMA region in which the community is located. The analysis is both quantitative and qualitative. To the extent possible, benefit-cost ratios were calculated for all "project" and "process" activities in the communities funded by FEMA grants. Project activities include physical measures to avoid or reduce damage resulting from disasters. Typically they involve elevating, acquiring, and/or relocating buildings, lifelines or other structures threatened by floods; strengthening buildings and lifelines to resist earthquake or wind forces; and improving drainage and land conditions (MMC, 2002). Process activities lead to policies, practices, and projects that reduce risk. These efforts typically focus on assessing hazards, vulnerability and risk; conducting planning to identify projects, policies, and practices and set priorities; educating decision-makers, and building constituencies and political will; and facilitating the selection, design, funding, and construction of projects (MMC, 2002). As part of the analysis, synergistic activities were also assessed.[1] Through the use of activity chronologies, variables and factors (e.g., institutionalization) that affect a community's ability to undertake and implement hazard mitigation activities are described.

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[1] Synergistic activities are activities or effects that follow or accompany the award of FEMA grants for project mitigation or process mitigation activities, or the strong expectation that a grant would be awarded, that reduce risks (or increase benefits of risk-reduction activities) from floods, earthquakes, and severe winds. The synergistic activities identified were not funded by FEMA.

Chapter 6, Benefit-Cost Analysis of FEMA Mitigation Grants, contains the major findings of the grant analysis. The National Emergency Management Information Systems (NEMIS) database served as the starting point. A detailed summary of FEMA's mitigation activities ─ delineated by hazard, mitigation type, costs, etc., as documented by the NEMIS database ─ is provided. The study used a stratified sample to represent the entire population of mitigation activities funded by FEMA between 1993 and 2003. The major focus of this chapter is the analytical results. Benefit-cost ratios are calculated for six different strata: project activities for wind, flood, and earthquake and process activities for wind, flood and earthquake. In addition to delineating the net benefits of mitigation to society, this chapter also provides insights into impacts (or savings) to the federal treasury.

Chapter 7, Summary, identifies the key findings from the benefit-cost analysis of FEMA mitigation grants and the community studies. It also indicates how FEMA-funded mitigation activities have fared with respect to anticipated benefits and actual mitigation costs. From an analysis of eight communities that have received FEMA hazard mitigation funds, it is clear additional benefits accrue, in large part, as result from FEMA-funded mitigation activities. This chapter attempts to put into perspective the magnitude of these synergistic benefits and the types of linkages with FEMA-funded efforts.

A series of technical appendices contain benefit-cost analysis data collection forms, community studies field research documentation, explanations of the methods used to develop information on cost and benefits, a detailed listing of assumptions and limitations of this study, and other background information. Every attempt has been made to document assumptions, methodologies, and data to permit the reader to fully understand this study and perhaps undertake additional analyses.

A second document, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, *Volume 1 – Findings, Conclusions*, *and Recommendations* includes a brief overview of the study findings and the MMC Board's conclusions and recommendations based on those findings.

Chapter 2
PRINCIPLES AND DEFINITIONS

This chapter discusses the guiding principles of this study, describes the key methods that define its scope and depth, and presents important definitions and delineations that help to connect its different parts. The discussion helps lay the foundation for more detailed and complex summaries of the approach to assessing mitigation benefits. The reader should note that, while the discussions are general, some parts may apply more to a particular study component. For example, the discussion on case study principles is designed to frame the approach used in the community studies. Similarly, the section on synergistic activities focuses on key concepts used in the community study analysis to define the extended benefits of mitigation. All other discussions apply to both study components.

2.1 Benefit-Cost Analysis

A benefit-cost analysis requires that hazard mitigation costs and hazard losses be measured in terms of the value of all resources used (or destroyed) and at prices that represent their efficient allocation ─ not necessarily at market prices, which often do not account for inefficiencies or may not even exist in cases such as environmental resources (Boardman et al., 1996). In addition, transfer payments (e.g., taxes and subsidies) should not be included because they do not represent the use of resources, but rather a shift of funds from one entity to another. This method avoids double-counting and covers all resources, including nonmarket resources (Ganderton, 2004). In practice, standard accounting categories, such as asset purchase cost and lost sales, represent proxies for the ideal resource valuation (efficiency prices) because of limitations of measurement.

To complete a benefit-cost analysis, it is necessary to estimate all costs and all benefits. The cost side is usually the straightforward assessment of capital expenditures, and operation and maintenance expenses (where applicable). Benefits, or avoided losses from hazards, are much more difficult to assess because they are not limited to a single structure or moment in time and are highly uncertain over the short term. Accordingly, elaborate methods (discussed in the following sections) have been developed to estimate these benefits by first estimating the various categories of losses from hazards in the absence of, and in the presence of, mitigation. Two complications arise in estimating the future benefits of hazard mitigation. First is the need to discount them to a present value so that benefits accruing at different times can be made comparable. (An exception is that it is considered inappropriate to discount the economic value of avoiding future statistical deaths and nonfatal injuries. See Section 4.2.2.3.) Second is the need to express them in probabilistic terms (the number of times something will probably occur over the range of possible occurrences) to capture their uncertain frequency of occurrence and magnitude.

Benefit-cost analysis is widely used by the federal government. It was first made a requirement in the Flood Control Act of 1936 where Congress stipulated that the U.S. Army Corps of Engineers could only undertake flood control projects if the benefits of the projects exceeded

their costs. Today, a benefit-cost analysis is required before many public projects or initiatives can be approved, including FEMA hazard mitigation grants. Several government documents specify formal rules and procedures for undertaking benefit-cost analyses (U.S. Government Accountability Office, 2002; Office of Management and Budget, 1992). Benefit-cost analysis methodologies have been refined by economists, other social scientists, scientists, engineers, and ethicists for over 60 years. Contentious issues, such as discounting, have been resolved by National Academy of Science panels.

FEMA follows established benefit-cost analysis practices, including the publication of its own guideline documents and the circulation of illustrative examples (e.g., NIBS and FEMA, 2003a; 2003b). The FEMA mitigation grant application process requires completion of a benefit-cost analysis. Approval hinges to a great extent on demonstration of positive net benefits, which is equivalent to a benefit-cost ratio exceeding 1.

The benefit-cost analyses in FEMA grant application files provide important information. However, not all of it could be used in this study for a variety of reasons including the following:

1. Because this study is intended to be an independent assessment, benefit-cost ratios in FEMA grant files were not used or validated. However, the basic data from the grant application files on the characteristics of structures and mitigation projects were used to estimate benefits.

2. The benefit-cost analyses in the FEMA grant applications examined typically did not include a wide range of benefits, especially those difficult to quantify (e.g., avoidance of indirect business interruption, environmental damage, and societal impacts). This study develops new methods to quantify such additional benefits.

This study does, however, use mitigation cost data from FEMA files. The first approximation to cost is the FEMA grant allocation, a matter of public record and a definite expenditure. This must, however, be adjusted for any significant transfer payments (e.g., taxes). It also should include any matching funds from other government entities or the private sector used to carry out the mitigation activity.

One important issue was the selection of an appropriate discount rate. The real rate used for discounting is based on market interest rates. The base case real discount rate used is 2 percent, the same rate that is recommended by the Congressional Budget Office (CBO) (Congressional Budget Office, 1998). This rate is based on a CBO estimate of the long-term cost of borrowing for the federal government and is generally considered a conservative estimate of the long-term real market risk-free interest rate. The Office of Management and Budget (OMB) recommends that the real rate should be based on the rate of return to private investment (Office of Management and Budget, 1992). The sensitivity tests conducted for this study were performed using 0 percent as a lower bound and 7 percent as an upper bound. A 7 percent rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. This rate is generally considered to be an upper bound for federal projects because the rate of return to public-sector projects is typically assumed to be lower than private-sector projects.

Another important issue in the calculation of benefits is the selection of the effective life of a mitigation effort, which is used to calculate the present value of avoided future losses. Consistent with common practice in the new design or rehabilitation of ordinary (non-essential or hazardous) buildings, the present study applies a 50-year effective life to mitigation efforts for ordinary buildings; a 100-year effective life is assumed for lifeline facilities.

2.1.1 Measures of Costs

The costs of hazard mitigation are all the resources used — not just the explicit "out-of-pocket" expenditures on labor, capital, materials, and services but also more subtle categories. The latter include implicit, or "opportunity costs" that refer to the use of inputs (e.g., donation of labor time, the carrying cost of capital) which may not have been charged to the mitigation activity but could have been productive elsewhere. The value of the foregone opportunity represents a type of implicit cost. Examples are government administrative costs and the value of non-priced environmental services. Environmental impacts can be either positive or negative (e.g., whether a wetland was destroyed in the course of building a drainage project or created by rezoning land).

There are also indirect costs and spillover effects of mitigation. An example of the latter is a change in real estate values, again possibly either positive or negative. Because nearly all of the mitigation grants analyzed applied to individual structures or a small cluster of private residences, spillover effects are assumed to be negligible, at least in the benefit-cost analysis of FEMA mitigation grants. An additional consideration is "ripple effects" of mitigation activities. These represent the additional jobs and income generated because of backward and forward economic linkages of the construction or operation of a mitigation project or process. Because of the controversy over whether to treat this category as a cost or a benefit and because of an Office of Management and Budget (1992) stricture against including it in official federal government benefit-cost analyses, this category also is omitted from the benefit-cost analysis of FEMA mitigation grants. This effect, however, is addressed (to a certain extent) in the community studies (Section 2.5.2, Synergistic Activities).

Independent estimates of the costs of administering FEMA grants could not be obtained, nor could estimates of the savings of reduced costs of administering post-disaster recovery because of mitigation. The omission of these two administrative cost categories is unlikely to have a significant effect on the *net* benefit calculations.

The primary approach to cost estimation involved use of entries from the National Emergency Management Information System (NEMIS) database on basic project and process costs. These cost entries are entered into NEMIS from grant applications and were considered to be reliable primary data for this study. On the other hand, estimation of nonmarket costs is based on the data-transfer methods that involve applying empirical results from related contexts to individual project and process grants in the sample.

In summary, the following hazard mitigation cost categories addressed in this study are:

1. Cost of project mitigation activities (e.g., building retrofit, bridge improvement, equipment tie-down, buyouts);

2. Cost of process mitigation activities (e.g., education, community organization to deal with hazards, vulnerability analysis); and

3. Nonmarket costs (e.g., effects on wetlands or historic sites).

2.1.2 Measures of Benefits

The benefits of hazard mitigation are the avoided losses that would have occurred if the mitigation activity had not been implemented. It is important at the outset to note two key differences between mitigation costs and benefits. Mitigation costs are incurred primarily during a short period, such as during construction, and they are relatively certain. The only exception pertains to operating costs and maintenance costs, but these costs are usually relatively minor in comparison to construction costs. Mitigation benefits, however, accrue over the useful life of the project or process activity and are highly uncertain over the short termbecause they are usually realized only if natural hazard events occur. At best, the expected value of benefits of mitigation measures currently in place can only be approximated by multiplying the potential total benefits by the probability distribution of hazard events. In addition, benefits must be discounted to present value terms to account for the time value of money.

The various categories of hazard mitigation benefits addressed in this report are:

1. Reduced direct property damage (e.g., buildings, contents, bridges, pipelines);

2. Reduced direct business interruption loss (e.g., damaged industrial, commercial, and retail facilities);

3. Reduced indirect business interruption loss (e.g., ordinary economic "ripple" effects);

4. Reduced (nonmarket) environmental damage (e.g., wetlands, parks, wildlife);

5. Reduced other nonmarket damage (e.g., historic sites);

6. Reduced societal losses (casualties, homelessness); and

7. Reduced need for emergency response (e.g., ambulance service, fire protection).

The standard loss category, direct property damage, is almost always reported in the aftermath of a natural disaster. Some of the other categories, such as direct and indirect business interruption losses, have been estimated more frequently in recent years. However, other categories, such as environmental damage and societal losses, have rarely been estimated, with the exception of casualty losses. The absence of estimates is due not to lack of legitimacy but rather to lack of data.

2.2 Loss Estimation Modeling

Compared to benefit-cost analysis, loss estimation modeling is relatively new, especially with respect to natural hazard assessment. Although some studies were conducted in the 1960s, only in the 1990s did loss estimation methodologies became widely used. A major factor in this development was the emergence of geographic information systems (GIS) technology that

allowed users of information technology to easily overlay hazard data or information onto maps of various systems (e.g., lifeline routes, building data, population information).

Loss estimation methodologies are now vital parts of many hazard mitigation studies. They are typically used to forecast the potential impacts of different hazard scenarios (typically used for planning), to project losses in an actual event (when used in conjunction with near real-time sensor systems, such as the ShakeMap system deployed by the U.S. Geological Survey), and to assess the benefits of a mitigation activity such as structural retrofit. A National Research Council (NRC) report, *Impacts of Natural Disasters* (NRC Committee on Assessing the Costs of Natural Disasters, 1999), also discusses the importance of relying on loss estimation modeling as a means of tracking and monitoring the costs of natural disasters. Because current government accounting systems are inadequate when it comes to totaling the costs of a disaster, the NRC report suggests that loss estimation modeling could provide surrogate means of tracking these costs.

FEMA has recognized the value of loss estimation modeling as a key hazard mitigation tool. In 1992, FEMA began a major effort (which continues today) to develop standardized loss estimation models that could be used by nontechnical hazard specialists. The resulting tool, the software program called HAZUS®MH, currently addresses earthquake, flood, and wind. It was used extensively in this study as discussed in Section 4.2.

2.2.1 Basic Components

To fully understand the loss estimation process, it is important to recognize the basic components of the mathematical model used to estimate loss (referred to here as the loss model). Regardless of the hazard being analyzed, a loss estimation model will consist of three basic components:

1. A hazard model that characterizes the likelihood and severity of the hazard;

2. An exposure model that quantifies the assets at risk in the area affected by the hazard; and

3. A vulnerability model that relates the damage potential of various assets to varying hazard levels.

Characterizing the hazard often involves the use of statistical or probabilistic models. Generally, an analyst is interested in two aspects of hazard: how frequently will the hazard occur over a designated period of time and what is the greatest intensity event that can be expected over a period of time. Probabilistic models that consider the relative frequency of past events are generally employed to determine frequency. For some hazards, this assessment may be easy; for hazards that occur only infrequently, this may be the most complex task of the entire loss estimation process.

Assessing the degree of exposure also is complex. Exposure applies to characterizing what is at risk ─ for example, the number of buildings, the amount of infrastructure within a region, or the number of people exposed to the hazard. In addition, quantification of exposed assets includes a characterization that often requires a definition or assignment of structural types and values.

Ironically, this component is often the most unsubstantiated part of the model. Although it has the potential for being 100 percent reliable, it generally relies on crude approximations because of the overwhelming resources needed to develop an accurate representation. In the present application, the nature of the facilities whose risk has been mitigated is crucial information, because costs and benefits are calculated largely based on specific projects, rather than on the nature of the general building stock.

The last major component is the vulnerability model. Often referred to as a fragility or damage function, this model directly relates the amount of damage or functionality expected to the level of hazard (or intensity) experienced. Significant research has been conducted in developing facility-specific functions for buildings and lifeline components. In many cases, the uncertainty or variability associated with these models is expressed in statistical (e.g., standard deviations) or probabilistic terms.

To complete a credible loss assessment, other modules or elements are needed. This procedure begins with translating physical property damage into dollar loss. Certainly, the value of the damaged facility is a key part of determining the eventual cost of repairs. For many facilities, however, the cost of downtime translated into lost production is also a major element of expected loss. The role of these other factors is discussed in the next section.

2.2.2 HAZUS®MH

HAZUS®MH is built on an integrated GIS platform that estimates losses due to earthquake, flood, and wind events. The software program is composed of seven major interdependent modules. The connectivity between the modules is conceptualized by the flow diagram in Figure 2-1. The following discussion provides a brief description of each module; detailed technical descriptions can be found in the HAZUS®MH Technical Manuals (NIBS and FEMA, 2003a, 2003b, 2003c).
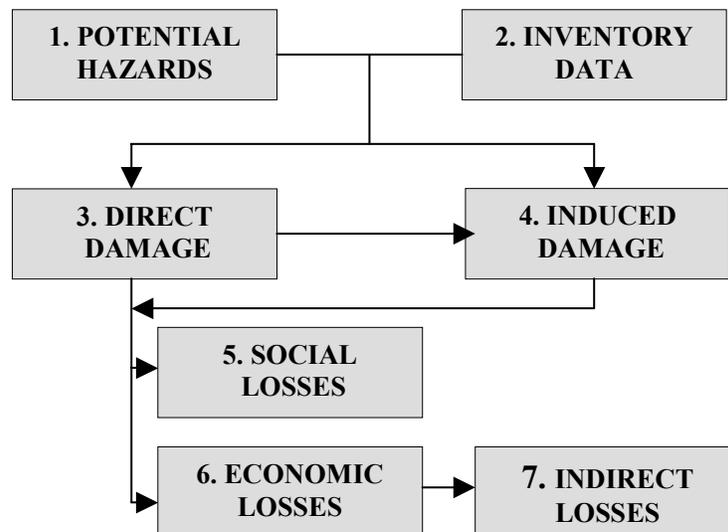
Figure 2-1 HAZUS®MH modules.

<u>Potential Hazards (1)</u> ─ The potential hazard module estimates the expected intensities or hazard severities for three hazards: earthquake, flood, and wind. For earthquake, this would entail the estimation of ground motions and ground failure potential from landslides, liquefaction, and surface fault rupture. For flood, this involves the estimation of flood heights or depths. For wind, this entails the estimation of wind speeds and wind-born debris. For a probabilistic analysis, the added element of frequency or probability of occurrence would be included.

<u>Inventory Data (2)</u> ─ A national-level exposure database of the built environment provided with HAZUS®MH allows the user to run a preliminary analysis without collecting additional local information or data. The default database includes information on the general building stock, essential facilities, transportation systems, and utilities. The general building stock data are classified by occupancy (residential, commercial, industrial, etc.) and by model building type (structural system, material of construction, roof type, and height). The provided mapping schemes are state-specific for single-family dwellings and region-specific for all other occupancy types. In all cases, they are age and building-height specific.

<u>Direct Damage (3)</u> ─ This module estimates property damage for each of the four inventory groups (general building stock, essential facilities, transportation, and utilities), based on the level of exposure and the vulnerability of structures at different hazard intensity levels.

<u>Induced Damage (4)</u> ─ Induced damage is defined as the secondary consequence of a disaster event on property. Fire following an earthquake and accumulation of debris are examples.

<u>Social Losses (5)</u> ─ Societal losses are estimated in terms of casualties, displaced households, and short-term shelter needs. The casualty model provides estimates for four levels of casualties (minor injuries to deaths), for three times of day (2:00 a.m., 2:00 p.m., and 5:00 p.m.), and for four population groups (residential, commercial, industrial, and commuting). The number of displaced households is estimated based on the number of structures that are uninhabitable, which is in turn estimated by combining damage to the residential building stock with utility service outage relationships.

<u>Economic Losses (6)</u> ─ Direct economic losses are estimated in terms of structural and nonstructural damage, contents damage, costs of relocation, losses to business inventory, capital-related losses, wage and salary income losses, and rental losses.

<u>Indirect Economic Losses (7)</u> ─ This module evaluates region-wide ("ripple") and longer-term effects on the regional economy from earthquake, flood, and wind losses. Estimates provided include changes in sales, income, and employment by sector (i.e., commercial, industrial, retail).

The various modules of the HAZUS®MH software have been calibrated using existing literature and damage data from past events. For earthquake, two pilot studies were conducted several years ago for Boston, Massachusetts, and Portland, Oregon, to further assess and validate the credibility of estimated losses.   A similar testing and validation effort was conducted for flooding and hurricane wind.

2.3 Benefit Transfer Methods

Not all mitigation measures evaluated in this study can be analyzed using traditional evaluation methods. Thus, an alternative approach for assessing mitigation benefits was needed. For environmental and historic building benefits, a feasible approach for measuring the benefits of hazard mitigation is the benefit transfer approach (Brookshire and Neill, 1992; Bergstrom and DeCivita, 1999). The approach was developed for situations in which the time and/or money costs of primary data collection are prohibitive. In this approach, environmental benefit estimates from other case studies are spatially and/or temporally transferred to the policy case study.

The benefit transfer approach can be used to quickly adapt benefit estimates from one case study to another and to develop those estimates around the particular parameters of the case study of interest. Benefit transfer is also increasingly being applied to estimating many categories of public policy benefits (ranging from economic to societal), not just the environmental aspects. There are several types of benefit transfer. For decades, economists have used the benefit estimate transfer approach in which researchers obtain a benefit estimate from a similar study conducted elsewhere and use it for a current policy analysis case study (e.g., Luken, Johnson, and Kibler, 1992). This study relies predominately on standard applications of benefit estimate transfer. The application of this approach to estimating the benefits of grants for process mitigation activities, however, stretches this method to its limits because there are no studies that measure the benefits of process activities. Studies of the implementation of process activities in related areas (e.g., radon risk communication) were used instead. Hence, this modified application is referred to as a surrogate benefit approach.

More recently, benefit function transfer and meta-analysis function transfer have been developed in an attempt to transfer benefits more accurately. Benefit function transfer uses a statistical model of benefits developed at the original study site to estimate benefits at the subsequent policy site application (e.g., Loomis, 1992). Characteristics from the policy site are substituted into the model from the study site to tailor benefit estimates for the policy site. Benefit function transfer is generally preferred to benefit estimate transfer but was determined to be too cumbersome for use in this study.

Meta-analysis is a general term for any methodology that summarizes results from several studies. Benefit estimates gathered from several studies serve as the dependent variable in regression analysis, and characteristics of the individual studies (e.g., water quality, type of survey methodology) serve as the independent variables (e.g., Rosenberger and Loomis, 2000). Meta-analysis functions were used in this study when available.

2.4 Case Study Principles

Case studies were employed to explore more fully the impact of hazard mitigation activities in a single community. The methods employed in the community studies followed traditional case study principles best expressed in U.S. Government Accountability Office (1990) and Yin (2003). They were selected to meet the independent study's goals and to address four tests commonly used to establish the quality of empirical social research. The tests, according to Yin (2003), are:

1. Construct validity (to establish correct operational measures for the concepts being studied);

2. Internal validity (to establish a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships);

3. External validity (to establish the domain to which a study's findings can be generalized); and

4. Reliability (to demonstrate that the operations of a study (e.g., such as the data collection procedures) can be repeated with the same results.

To meet these tests and the study's goals, the following techniques were used:

1. Purposive sampling ─ Communities were selected because they had received numerous FEMA hazard mitigation grants and the sum of their grants exceeded $500,000. Other selection criteria included geographical disparity and instances of earthquake, flood, and wind grants; they were not chosen because they might be considered best or worse cases, typical communities, or have special characteristics.

2. Reliability ─ Use of a case study protocol; development of a case study database.

3. Measurement or construct validity ─ Multiple sources of evidence were used (document collection, structured telephone interviews, open-ended on-site interviews, archival research) and a chain of evidence was established.

4. Data analysis or internal validity ─ Triangulation (comparison of multiple, independent sources of evidence before reaching conclusions); ordering information chronologically for time series analysis, rival explanations (developing alternative interpretations of findings and testing through search of confirming and non-confirming information until one hypothesis is confirmed and the others ruled out); plausibility after completely considering all evidence.

5. Handling multiple-site data sets (internal and external validity) ─ Matrices of categories related to the evaluation questions; flow charts listing critical decisions to illustrate each site and to use for comparisons; use of nonquantitative time series analysis for explanation building.

2.5 Definitions

In the conduct of this study, there are several key concepts that help to establish the scope and depth of the analysis. These are discussed below.

2.5.1 Process and Project Activities

An important definitional distinction in this study refers to "project" mitigation and "process" mitigation. As indicated earlier, project activities include physical measures to avoid or reduce damage resulting from disasters. Typically they involve elevating, acquiring, and/or relocating buildings, lifelines or other structures threatened by floods; strengthening buildings and lifelines to resist earthquake or wind forces; and improving drainage and land conditions (MMC, 2002). Process activities lead to policies, practices, and projects that reduce risk. These efforts typically focus on assessing hazards, vulnerability and risk; conducting planning to identify projects,

policies, and practices and set priorities; educating decision-makers, and building constituencies; and facilitating the selection, design, funding, and construction of projects (MMC, 2002).

Because of the wide disparity in the types of studies that fall under each category, different evaluation approaches were used in the assessment of benefits. For most project activities, it was possible to use some type of quantitative method or tool (e.g., HAZUS®MH) to determine benefits. For process activities, benefit transfer methods were a key component in the assessment of mitigation benefits. Chapter 4 discusses in detail the various methods used to quantify mitigation benefits for both project and process activities.

2.5.2 Synergistic Activities

One potential benefit of a FEMA grant is that a community may be able to use it as seed money or otherwise leverage the grant funds to expand existing and/or to develop new mitigation programs. A FEMA mitigation grant also may lead to increased economic activities. However, communities may develop mitigation programs without FEMA influence. During community studies, some activities were found that were heavily influenced by the FEMA-funded grants and others were not − they were the result of other community processes. Thus, a scheme to categorize community activities that follow FEMA project or process grants was developed.

Synergistic activities are activities or effects, which reduce risks (or increase benefits of risk-reduction activities) from floods, earthquakes, and severe winds that follow or accompany the award of FEMA grants for project or process mitigation activities or the strong expectation that a grant would be awarded. These activities are not funded by FEMA and can take the form of spin-off activities, collateral activities, or spillover effects.

Spin-off activities are synergistic mitigation activities that directly (an action that would not otherwise have taken place) or indirectly (accelerated timing of an action that would have taken place eventually) result from or are enabled by FEMA hazard mitigation grant support, but which were not directly funded by FEMA. Collateral risk-reduction activities are activities that are not spin-off activities because FEMA hazard mitigation grant support had no significant impact on their content or timing. Spillover effects of mitigation include direct and indirect increases in economic activity or value of assets in the more conventional use of the terms direct (i.e., increase in business activity of new or revitalized enterprises or increase in property value) and associated indirect (i.e., ripple effects).

To determine if a community activity was a spin-off activity, it was asked whether there was a high chance that the activity in question was financed or supported because FEMA provided support (or was strongly expected to provide support) for another process or project. If a preponderance of evidence from telephone interviewees, face-to-face interviewees, and contemporary documents indicated that the answer was "yes," then the activity in question was categorized as a spin-off activity. An example of a spin-off activity occurred in Jefferson County, Alabama, where following the implementation of a FEMA grant to buy out substantially damaged houses after a flood, the county council passed a regulation that mandates that the county set aside $2M annually for the specific purpose of removing houses from the floodplain. In this situation, the houses purchased from the FEMA grants funds were the first that the county

removed, and both interviewees and documents indicated that the subsequent regulation was a direct result of the FEMA grant.

If the answer to the above question was "no," it was asked whether the FEMA grant accelerated the activity in question. If the answer was "yes," the activity in question was categorized as a spin-off activity. If the answer was "no," the activity in question could not be a spin-off activity, but could still be a collateral activity.

Chapter 3
DATA COLLECTION, PROCESSING, AND ANALYSIS

This chapter introduces the primary datasets for both the benefit-cost analysis of FEMA mitigation grants and the community studies. These datasets were used to:

1. Establish the costs of all FEMA mitigation activities;

2. Help select a stratified sample for the benefit-cost analysis of FEMA mitigation grants and the communities evaluated in the community studies analysis; and

3. Help support comparative analysis studies of community mitigation.

These primary datasets, how information was developed using them, and the additional datasets developed during the course of this project are described below.

3.1 Existing Data Sources

3.1.1 FEMA NEMIS Database

The National Emergency Management Information System (NEMIS) database is used by FEMA to monitor the status of hazard mitigation grants. The NEMIS database was used to help select the stratified sample of grants for the benefit-cost analysis of FEMA mitigation grants and the communities for in-depth analysis. Key fields in this database are: FEMA region, disaster declaration number and project numbers, subgrantee name, project title, mitigation type, project status (void, withdrawn, denied, pending, approved, closed), total approved net eligible project cost, and Federal share obligated to date.

These data identify general location (city or county), cost of mitigation, and often (but not always) the type of risk being mitigated, and so were useful in selecting sample grants for detailed examination. However, the NEMIS database does not provide several pieces of information crucial to estimating mitigation benefits, most notably: precise location (latitude, longitude, and ground-floor elevation of affected properties for flood hazard mitigation projects); engineering and architectural information (structure type, number of stories, square footage, era of construction, roof configuration, etc.); values exposed to risk (building replacement cost, content replacement cost, number of occupants, economic consequences of business interruption, etc.); and, in many cases, detailed descriptions of the mitigation work performed.

The NEMIS database provides a current, cross-sectional snapshot of the status of FEMA-funded grants but provides complete data for only those projects that are "closed." Information for all other FEMA-funded grants either reflect the project descriptions and costs indicated in the original project application or, if changes have been approved, information from the last posted quarterly report.

In most cases, probably over 95 percent, information in the database proved to be accurate. There were, however, some recurrent problems that became apparent when grant files were

reviewed or verified during community site visits. For example, sometimes the subgrantee name was too long to fit the allocated space in the database, and this resulted in an occasional misidentification. Also, mitigation types were often chosen to fit a list of very general, predetermined categories, and some projects were significantly different from what was expected. For example, in the list of flood-induced buyouts of private property in riverine areas, one buyout would have been more accurately caused by a landslide debris flow in an alluvial fan than by flooding.

In many cases, after funds were allocated for hazard mitigation projects, some projects were cancelled, not completed, or reduced in scope and unspent or "de-obligated" federal funds were often reallocated after subsequent disasters. The reallocations often were for large projects with many buyouts (in which properties are purchased, the buildings removed, and the land dedicated to open space) or elevations (in which buildings are physically raised and their foundations altered so that the first floor is above the 100-year flood elevation) that could be divided so that some could be funded from separate disaster declaration funds. In these situations, a total buyout of multiple properties in a community was funded by two or more disaster grants. Consequently, in a limited number of cases the number of NEMIS grants exaggerated the number of actual projects.

According to the NEMIS database (as of 5 June 2003), there were 9,719 project applications for all hazards since approximately 1989. The disposition or status of these applications is presented in Table 3-1. A little over 40 percent of these applications represented completed projects and about 30 percent were still active. All applications were funded by the following programs:

1. Various supplemental appropriations and appropriations to serve unmet post-disaster reconstruction needs,

2. Flood Mitigation Assistance,

3. Hazard Mitigation Grant Program, and

4. Project Impact.

Table 3-1 Status of applications in NEMIS database (as of 5 June 2003)

Current Project Status	Count
Closed	4,265
Approved	2,967
Denied	793
Withdrawn	783
Pending	527
Void	279
Null	104
2nd Appeal	1
Total	9,719

Of the 7,232 funded mitigation activities (i.e., approved and closed), 5,479 were associated with flood, wind (including hurricane and tornado), or earthquake. Because other hazards such as winter storm, fire, and terrorism were outside of the scope of this project, grants to reduce the risks from these hazards were excluded.

Table 3-2 presents the approximate number and cost of funded grants by hazard type. Approximately 64 percent of the funded projects dealt with the mitigation of flood hazards, while 29 percent addressed wind, and 7 percent addressed earthquake hazards. Flood grants represent 63 percent of costs, while wind and earthquake represent 11 percent and 27 percent, respectively. Earthquake mitigation efforts are generally more costly than flood or wind ─ $2.4 million for the average earthquake grant, compared with $630,000 and $240,000 for flood and wind, respectively.

**Table 3-2 Number and cost
of funded grants by hazard type**

Hazard Type	Grants	Cost ($M)
Wind	1,572	374
Flood	3,512	2,217
Earthquake	395	947
Total	5,479	3,538

A breakdown of grant types indicates that 90 percent of the grant applications were for project mitigation activities and 10 percent were for process mitigation activities. In terms of cost, grant applications for process mitigation activities accounted for only 5 percent of total costs.

Figure 3-1 shows the distribution of grants by FEMA region. The largest number of grants (32 percent) is associated with Region IV, which includes Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The greatest grant amount (28 percent) is associated with Region IX, which includes California, Arizona, Nevada, and Hawaii.
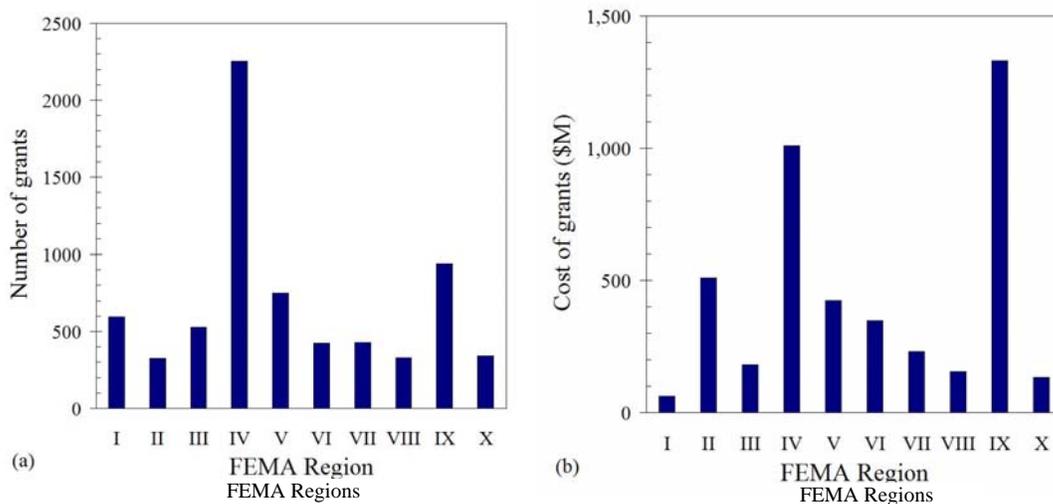
Figure 3-1 FEMA mitigation grants by region: (a) number and (b) total cost.

Figure 3-2 shows the distribution of FEMA grants by year of declaration (i.e., the year the disaster was officially declared by the federal government). Although the largest number of funded projects occurred in 1998, the highest costs were experienced in 1994, the year the Northridge, California, earthquake occurred.
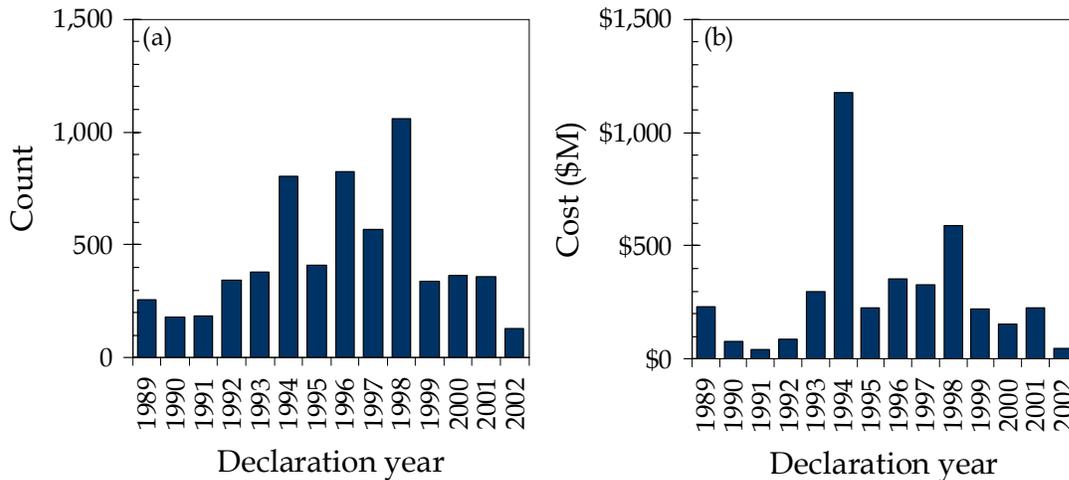
Figure 3-2 Mitigation grants by year of declaration.

3.1.2 Hazard Mitigation Grant Program and Flood Mitigation Assistance Grant Files

An examination of grant files was necessary to supplement the NEMIS data, particularly for precise location, engineering and architectural information, values exposed to risk, and in many cases, detailed descriptions of the mitigation work. Grant files generally were kept by the FEMA regional office overseeing the grant, the state emergency management office, and the local community or subgrantee. FEMA provided copies of files for review or the files were examined in FEMA offices. Files from the FEMA regional office and the state emergency management office were found to be nearly identical and were organized into similar folders that separated documents by topics such as financial, benefit-cost, environmental, project application, and correspondence. The only consistent differences were in correspondence and the retention of original notes that accompanied sent mail. Files exist at both locations for all grants listed in NEMIS.

Documents retained at the state and federal FEMA region were typically also found at the local community; however, they were not organized in the same way (e.g., in some communities, all documents were located together while in others documents were retained in the files of the staff or consultants who created them). Unlike the states and the FEMA regions, which broke up lengthy documents and filed different sections under the appropriate topic, the local communities kept their documents whole. Also, communities retained internal project analyses and consultant reports that seldom made their way into the state or federal files (e.g., the state and FEMA region

files might contain a summary of a benefit-cost analysis while the community file would contain the lengthy analysis developed by a consultant that was used to create the summary).

Grant applications were the main source of information for the FEMA Hazard Mitigation Grant Program (HMGP) and Flood Mitigation Assistance (FMA) funded grants. The grant applications usually contained fairly detailed explanations of the proposed mitigation activity, justifications for funding, engineering back-up if needed, descriptions of structures affected by the proposed activity, financial statements, benefit-cost analyses, and project schedules. There were, however, often more than one grant application if the project scope had changed. The grant applications were available at the regional, state and community sites and provided the basis for technical analysis.

During field visits, the initial contact person in each community normally provided access to the written documents, set up interviews with key informants to discuss the projects, and led tours of the project sites. The field visits usually were sufficient to clear up misconceptions and uncover information not available at the FEMA regional and state emergency management offices. Following field visits, detailed analyses of the FEMA-funded grants were conducted. If questions arose, knowledgeable persons were contacted by telephone and e-mail for additional information.

3.1.3 Project Impact Report Files

Project Impact was initiated by FEMA in 1997 to provide federal seed money to communities (selected by states) willing to develop long-term public-private partnerships that would result in self-sustaining disaster mitigation programs.[2] FEMA's goals were to support the creation of "disaster-resistant communities" and to reduce future federal post-disaster payments to these communities. It was believed that, if successful, Project Impact communities would become examples for other communities to emulate. Because of the nature of Project Impact, these grants and the reporting requirements are not like those for the other two FEMA hazard mitigation grants programs considered.

Whereas HMGP and FMA grant files were retained in folders with similar headings, Project Impact files were not. FEMA gave the communities great latitude in running their programs. Project Impact grants typically funded multiple activities determined by locals to be good mitigation investments. However, after the start of Project Impact, many initially proposed activities were further evaluated and were either cancelled or modified during the life of the grant and different activities were often added. If partners in the community offered to pay for a project, federal funds were moved to another activity. The dynamic nature of the projects was reflected in the files. There often was no clear indication of what set of activities was actually completed until a final report was prepared and, because the program ended suddenly, some communities did not keep their files or write final reports.

On-site interviews with Project Impact managers and the collection of additional printed documents were necessary to accurately identify the activities conducted under Project Impact. Most of the printed documents found in the communities had not been submitted to FEMA as

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[2] Project Impact ended in 2001; communities with existing grants were allowed to complete their activities.

part of their required financial quarterly reports. However, uncertainties concerning what activities were actually attempted and their status remained because key managers on several Project Impact grants had left and were unavailable for interviews.

3.1.4 Other Files

In the community studies, additional data were sought to describe and evaluate overall community hazard mitigation programs and to determine the effect of FEMA hazard mitigation grants on future community mitigation activities. Telephone and face-to-face interviews, field investigations, and email correspondence efforts were structured to cast a wide net to gather information concerning any hazard mitigation efforts that occurred before or after a community received FEMA grants, the sources of funding those efforts, any written documents describing the activities and their outcomes, and knowledgeable persons to contact to discuss the endeavors and locate the documents. Virtually all the documents identified through this process were collected during site visits although some were also located over the Internet.

Five types of written documents were found:

1. Local hazard mitigation plans;

2. Budgets, both annual and capital, that contained descriptions of mitigation activities carried out by local government agencies, spending amounts, and funding sources such as local revenues, dedicated property tax receipts, or bonds;

3. City and county council meeting minutes and resolutions related to mitigation activities;

4. Internal local government agency reports and studies done in-house or by contracted consultants describing proposed or existing mitigation activities, funding, and expected or actual results; and

5. Files, including project applications and supporting documents, for mitigation projects funded by state or non-FEMA federal agencies. Funding agencies included state emergency management offices and insurance departments, the U.S. Army Corps of Engineers, and the U.S. Department of Housing and Urban Development.

3.2 Other Primary Datasets

To supplement the databases above, several new datasets were developed during the course of this study. The discussion below presents data and information created as part of the community studies analysis; this is followed by a brief discussion on new data for the benefit-cost analysis of FEMA mitigation grants.

3.2.1 Community Studies

To supplement existing datasets and to provide more contextual information on community mitigation activities, additional data were collected through structured interviews with knowledgeable persons, field research, and limited archival record recovery. Figure 3-3

illustrates the data collection process. The process is comprised of four major phases: pre-interview activities; formal interviews; field visits; and data or information processing.

Pre-interview activities generally were conducted by field researchers. The main purpose of this activity was to collect from FEMA regional offices reports and data that would help in the conduct of any subsequent benefit-cost analysis and identify knowledgeable persons to interview. As part of the study protocol, FEMA Headquarters formally asked the regional offices to provide records to study personnel.
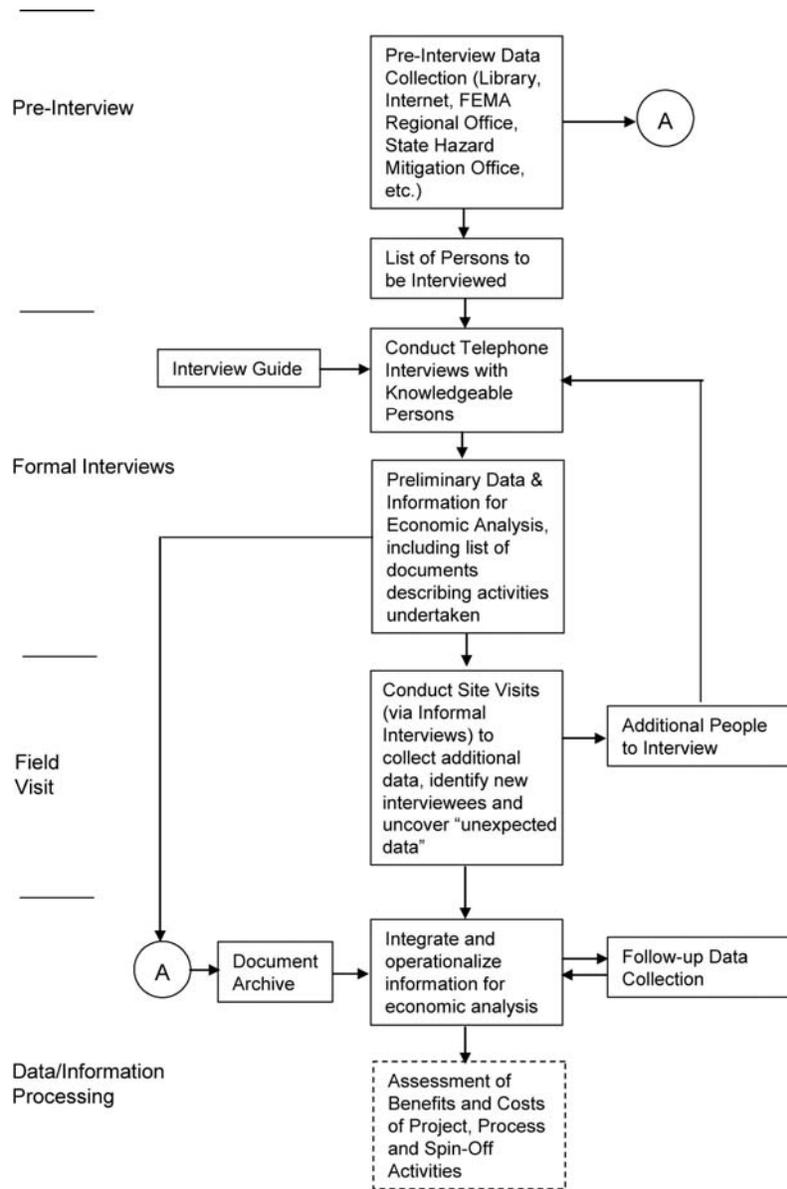
Figure 3-3 Data collection process for community studies; "A" denotes archive.

The next step involved telephone interviews with knowledgeable persons. These interviews provided an "insider's view" of hazard mitigation programs and projects that were being conducted within each of the communities investigated. As part of the data collection protocol, a detailed interview guide was created (see Appendix B) and tested during a pilot study involving Tulsa, Oklahoma.[3] Because the vetted guide was used in all subsequent interviews, the information gathered could be used as the basis for limited generalization. Some of the questions contained in the interview guide focused on the identification of possible synergistic activities that arose from FEMA hazard mitigation grants. These interviews also resulted in identification of additional people for face-to-face interviews.

Once telephone interviews were complete, face-to-face interviews were conducted with some of the knowledgeable people identified above and with others whose input was identified as valuable during field visits. In many communities, unexpected data and additional persons were found that led to further data analysis and telephone interviews. After the community site visit, any additional requests for data or clarifications were completed by telephone or by email.

3.2.2 FEMA Mitigation Grants

The FEMA regional office files were reviewed for all grants in the study sample. Electronic coding forms were created to extract data from the sample grant applications in a detailed and structured manner. The form for project mitigation activities contained 200 data fields for each property or location mentioned in the grant application. A coding database was compiled from the extracted data. Eventually 54,000 data items were entered into the coding database. The database addresses 1,546 properties in project mitigation activities and 387 distinct efforts in process mitigation activities.

Required data that appeared neither in the grant files at FEMA regional offices nor in the NEMIS database were acquired from the Internet or from other sources and inserted into the coding database. For example, square footage, number of employees, and precise street addresses for a number of mitigated buildings were acquired from the subgrantee's website or from the website of engineers or architects involved in the grant project. Latitude and longitude of most facilities were acquired using GIS software such as Microsoft Streets and Trips® (Microsoft Corp. 2004). Site soil classifications for earthquake projects were acquired using a geographic database created by the California Geological Survey (Wills et al., 2000).

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[3] The above concepts were considered in development of the standardized questionnaire used in telephone interviews and when selecting variables to assess from the 2000 census. Included in the standardized questionnaire were questions about non-FEMA-funded hazard mitigation activities, the history of hazard mitigation in the community, the existence of relevant state and local mitigation laws, the existence of active partners, perceived risk of disaster, perceived efficacy of hazard mitigation programs, and similar questions. Drawn from the 2000 census were data on population size, population growth rate, median age, percent non-white, percent of households with children under 18 and members over 64, percent of female-headed households with children, percent of families below the poverty line, percent in the labor force, and median family and per capita income. A more complete discussion of the demographics of each community is contained in Appendix C.

Chapter 4
METHODS OF ANALYSIS

This chapter is key to understanding the underlying methods used for both the benefit-cost analysis of FEMA mitigation grants and the community studies. In many cases, the same methods were used in both parts of the study. This was especially true in estimating expected losses and impacts to buildings, infrastructure, and exposed populations from earthquake and hurricane wind. In some cases, the benefit-cost analysis of FEMA mitigation grants performed a broader analysis of benefits by examining a wider range of impacts, especially to the environment and to historic structures. At the same time, the community studies offered additional insights into mitigation effectiveness by exploring how FEMA-sponsored mitigation activities percolate throughout the community in the form of synergistic activities ─ mitigation efforts that would not have occurred had it not been for the original FEMA grant. These different aims, seemingly similar, but in many ways very different, at times required that unique methodologies be developed and employed in both parts of this study.

This chapter is organized into four major parts. The first (Section 4.1) discusses the rationale behind the parallel components of the benefit-cost analysis of FEMA mitigation grants and the community studies. As suggested above, each study component is designed to answer a different part of the mitigation effectiveness question. The second and third parts of this chapter (Sections 4.2 and 4.3) introduce methodologies that are common between both components. HAZUS®MH was used for many of the loss calculations for both study components. This was especially true for earthquake and hurricane wind studies. However, in many cases, either because HAZUS®MH does not address certain kinds of losses or because the versions of HAZUS®MH that were available at the time of this study were not yet fully refined, it was necessary to develop alternative methodologies for loss estimation. Several of these methodologies are discussed in detail in this chapter; others that were important, but not key, to completing a particular phase of this study are mentioned briefly in this chapter and discussed in detail in the appendices to this report. The final two parts of this chapter (Sections 4.4 and 4.5) deal with the *sampling methods* and the overall methodologies for both the community studies and the benefit-cost analysis of FEMA mitigation grants. Appendix D contains the assumptions and limitations used in this study.

4.1 Parallel Study Components

What are the future savings to the nation that result from FEMA-sponsored hazard mitigation programs?

To answer this key question, the project was structured to provide for empirical research using a statistically representative sample of commonly used FEMA-funded mitigation activities as well as for research on mitigation activities carried out in specific community contexts. Together, these two study components:

1. Provide a robust assessment of mitigation effectiveness by quantifying the benefits and costs of FEMA-funded mitigation activities at both the national and at the community levels;

2. Identify the scope and breadth of mitigation benefits by examining both direct and indirect effects (e.g., business interruption to suppliers and customers of directly damaged structures);

3. Quantify the cost-effectiveness (i.e., benefits equal to or exceeding costs) of mitigation at a very high level (for the nation) and corroborate this assessment with specific benefit-cost analyses performed at the community level; and

4. Describe the extent to which FEMA-sponsored activities led to synergistic efforts that amplified the effects of the initial FEMA grant.

To compile or create the required methods of analysis, it is valuable first to understand the nature of FEMA's grant activities. Table 4-1 summarizes the types and distribution of grants within the present scope of study. The upper portion of the table details grants for project-type activities; the lower portion details grants for process-type activities. It shows that the most common grant for project mitigation activities involves acquisition, relocation, elevation, or floodproofing of property to mitigate flood (project type codes 200.1-204.4; 47 percent by cost). Various other small flood management projects (300.1-405.1; 18 percent by cost) and seismic structural retrofit (205.5-205.6; 13 percent by cost) represent half the balance. Regarding grants for process activities, Project Impact represents one third of the total cost, with miscellaneous grants (800.1; 18 percent by cost) and public awareness and education (100.1; 11 percent by cost) represent half the balance.

4.2 HAZUS$^{\circledR}$MH and Other Loss Estimation Methodologies

The section begins with a brief summary of HAZUS$^{\circledR}$MH and how it was used in this study. The basic structure of HAZUS$^{\circledR}$MH was introduced in Section 2.2.2. The reader is referred to the HAZUS$^{\circledR}$MH Technical Manuals (NIBS and FEMA, 2003a, 2003b, 2003c) for details on the model and the databases provided databases. The discussion below describes how HAZUS$^{\circledR}$MH was used to calculate loss and benefits for earthquake and for hurricane wind.

4.2.1 Direct Property Damage (Stock Loss)

Direct property damage (or direct stock loss) from earthquake and hurricane wind was calculated using the standard version of HAZUS$^{\circledR}$MH (an alternate methodology was used for floods as described in Section 4.3.1 below). HAZUS$^{\circledR}$MH is constructed so that for each of several non-exceedance frequencies (hazard levels), an excitation or hazard load can be calculated at each location of interest (e.g., for each building having hazard mitigation). In the case of earthquake, this is the performance point at which the building's pushover curve (as constructed from parameters in HAZUS$^{\circledR}$MH and from information in the grant application) crosses the seismic shaking response spectrum. In the case of wind, the excitation is peak gust velocity, as determined using the HAZUS$^{\circledR}$MH database.

Table 4-1 Distribution of grants in the NEMIS database

	Project Type Code	Mitigation Activity Type Description	% by No.	% by Cost
Project Activities	200.1-204.4	Acquire, Relocate, Elevate, or Floodproof Property	46	47
	205.3-205.4	Nonstructural Retrofitting/Rehabilitating – Seismic	3	9
	205.5-205.6	Structural Retrofitting/Rehabilitating – Seismic	4	13
	205.7-205.8	Retrofitting Structures – Wind	6	3
	206.1-206.2	Safe Room (Tornado and Severe Wind Shelter)	1	1
	300.1-405.1	Shoreline, Wetlands, Utilities, Flood Mgt, Roads, Bridges	28	18
	500.1-501.1	Flood Control - Major Structural Projects	2	6
	600.1-602.1	Warning Systems, Generators, and Other Equipment	10	3
		Grants for Project Mitigation Activities Total	100%	100%
Process Activities	90.4, 91.1	Mitigation Plan – Local Multihazard Mitigation Plan	16	5
	90.6, 92.1	Mitigation Plan – State Multihazard Mitigation Plan	3	5
	100.1	Public Awareness and Education	12	11
	101.1	Professional Education (Inspectors, Architects, etc.)	2	1
	103.1	Feasibility, Engineering and Design Studies	10	7
	104.1	Codes, Standards, Ordinances and Regulations	5	9
	105.1	Applied R&D in the Building Sciences	1	6
	106.1	Other Non-Construction (Regular Project Only)	8	4
	106.2	Project Impact	29	33
	600.1	Warning Systems	1	1
	800.1	Miscellaneous	13	18
		Grants for Process Mitigation Activities Total	100%	100%

The physical damage probability distribution to the facility was calculated based on the estimated performance point. In this context, the probability distribution represents the probability that the building will be in each of several damage states, e.g., light damage, moderate damage, etc.

Each damage state was associated with a mean damage factor. The estimated direct stock loss was the sum of the product of a damage-state probability, mean damage factor, and replacement cost. The process was repeated for each of several hazard levels. The scenario losses and the frequency of events were integrated to calculate an annual expected loss for the duration of the life of the building. This future stream of annual loss was then brought back to present value using standard discounting techniques. The difference between the direct stock loss before and after mitigation is the estimated mitigation benefit in terms of reduced direct stock loss.

4.2.1.1 Hazard Data

An important source for currently accepted hazard information for earthquake is the U.S. Geological Survey (e.g., Frankel et al., 1996). For hurricane wind speeds, HAZUS®MH uses a wind field model that is updated to include all historical storms of 1886 through 2001.

4.2.1.2 Exposure Data

FEMA grant applications provided data on the characteristics of the facilities being analyzed. Some grant applications, however, included poor geolocations; lacked data on structural types,

total value of structures, square footage, and/or occupancy; or did not fully describe the mitigation activity. To overcome these problems, the available data were supplemented by geo-locating (latitude and longitude) each property using street address and mapping software such as Streets and Trips® (Microsoft, 2004) and by inferring HAZUS®MH style structure type information using the description of the facility (its construction material and age) or readily available information about the facility from web pages that discuss the mitigation effort. Occupancy loads were often readily inferred from occupancy type and square footage (ATC, 1985).

4.2.1.3 Vulnerability Data

The vulnerability models built into HAZUS®MH formed the basis for all damage calculations. Those models come from a variety of sources (see the various HAZUS®MH Technical Manuals, 2003) and are based on empirical, analytical, and expert opinion data. In some cases, it was necessary to develop alternative vulnerability models to address special situations (e.g., assess the life-safety improvement produced by replacing pendant lights in California schools).

4.2.2 Business Interruption (Flow Loss)

This discussion focuses on direct business interruption impacts (i.e., business continuity losses caused by direct property damage to facilities or businesses or by interruption of utility lifeline services), indirect business interruption effects (i.e., losses that stem from an interruption of supplies or services upstream or downstream), and economic data used in the analysis.

4.2.2.1 Direct Business Interruption

HAZUS®MH was used to evaluate the business interruption benefits of hazard mitigation. This section focuses on the Direct Economic Loss Module and Indirect Economic Loss Module of HAZUS®MH (NIBS and FEMA, 2003a, b, c), which evaluate regional economic impacts of a disaster given estimates of physical damage developed by the HAZUS®MH damage modules. The Direct Economic Loss Model estimates capital stock losses from a disaster and various forms of direct regional income loss in dollar terms. The Indirect Economic Loss Model estimates indirect impacts (losses or gains) to regional income by major economic sector.

While property damage represents a decline in stock value and usually leads to a decrease in service flows, business interruption losses are a flow measure and most, but not all of them, emanate from property damage. However, direct business interruption losses can take place even in the absence of property damage. For example, a factory may be unscathed by a hurricane but may be forced to shut down if its electricity supply is cut off due to hurricane-induced damage to generation facilities or transmission or distribution lines.

Attention to flow losses represents a major shift in the focus of hazard loss estimation — that losses are not a definite or set amount but are highly variable depending on the length of the "economic disruption," typically synonymous with the recovery plus reconstruction periods (Rose, 2004a). This also brings home the point that disaster losses are not simply determined by the hazard intensity (coupled with initial vulnerability) but are also highly dependent on human ingenuity, will, and resources.

Another major aspect of loss estimation that needs to be incorporated to the extent possible is *resilience* or the ability to cushion losses by such actions as conservation, use of inventories, and input substitution (Tierney and Dahlhamer, 1998; Rose, 2004b). Several of these adaptations have been incorporated into the Indirect Economic Loss Model. However, one major aspect of resilience that is contained in the Direct Economic Loss Model is the "recapture" factor or the ability of a firm whose production has been interrupted to make up its lost output later by working overtime. Sectors, such as manufacturing, which have a steady demand and excess capacity have high recapture factors, whereas sectors like services (especially restaurants, hotels, theaters), which have a soft (time-related) demand and limited excess capacity, have low recapture factors.[4]

4.2.2.2 Indirect Business Interruption

Further losses stem not only from reduced production by businesses suffering property damage but also from several other sources (Brookshire et al., 1997). For example, additional losses stem from "ripple" effects to chains of upstream suppliers and downstream customers of damaged businesses or those cut off from their utility lifelines or access by their employees or customers. These indirect effects can be in the case of large, highly interdependent and self-sufficient regional economies, even larger than the direct flow losses (Rose and Liao, 2005).

A major feature of the HAZUS®MH Indirect Economic Loss Model is that consumers will have to redirect some of their ordinary spending to cover property repair/rebuilding costs. Thus, their overall expenditures are increased in the immediate aftermath of a disaster but are offset by a decrease of ordinary spending in subsequent years while they pay back loans or replenish savings. Borrowing costs further reduce subsequent spending. Economies are more resilient when borrowing costs, as well as the societal discount rate used to translate results into present value terms, are relatively low.

A major factor affecting overall business interruption losses was the level of outside aid, typically dominated by insurance payments and government relief. In cases where the proportion of outside aid was very high, this inflow, coupled with the positive ripple effects of reconstruction, can even result in the economy reaching a higher level of economic activity than prior to the disaster. However, this seemingly beneficial depiction of extreme hazard events is misleading in a pure benefit-cost analysis sense. The increased economic activity was mainly due to transfer payments coming into the region, but at the expense of economic activity elsewhere. From the standpoint of the nation as a whole, there was no net gain (see, e.g., Cochrane, 1997). Therefore, outside aid was omitted from the simulations to avoid including what are essentially artificial benefits.

Direct and indirect business interruption losses were not relevant in all cases. For example, a buyout in a residential area will not engender any such losses. Moreover, losses stemming from damage to schools or other public buildings will result in minimal business losses. On the supply side, they are not actual inputs to more standard economic activity (i.e., businesses). However, reduced operations of private sector buildings and some public buildings (e.g.,

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[4] HAZUS®MH also computes displacement costs for businesses and government in the Direct Economic Loss Model. Displacement for households is discussed in the Section 4.2.3.3 on societal impacts.

hospitals) will reduce orders for inputs into them. The impact will primarily be in terms of lost wages/salaries, because public services are highly labor intensive and require a much lower proportion of material inputs than conventional businesses, especially manufacturing. Even then, indirect effects from reduced wages/salaries will be minimal because empirical work indicates people maintain much of their spending by withdrawing from savings, especially for necessities, in the aftermath of a disaster. Moreover, HAZUS®MH takes this into account.[5]

4.2.2.3 Economic Data

HAZUS®MH contains some economic information, primarily on individual structures, but also, to a lesser extent, on the regional economies in which they are located. Examples include asset values and operating incomes (where applicable). However, these data are based on estimated functions of physical characteristics (e.g., translating square footage and other variables for individual building types into economic values). These "data," along with included values (i.e., the data entries in HAZUS®MH in place of region-specific data, usually based on national averages), represent what is called a Level 1 analysis in HAZUS®MH. The user has the option, however, to substitute data that are more accurate and perform a higher level or Level 2 analysis. Where possible, the project investigators improved the data to perform a Level 2 analysis.

HAZUS®MH economic data were supplemented with:

1. Primary data from FEMA grant application files regarding wage/salary income, capital-related income, rental income, and total operating revenue.

2. Secondary data collected from public sources on type of economy (service, trade, or manufacturing), unemployment rate (a proxy for excess capacity), and sectoral national averages of labor and capital income ratios per dollar of output (revenue).

Economic data generally were absent from the FEMA grant files. Moreover, some of the economic data entries that did appear in the files were vague. For example, information on operating revenues often applied to a company as a whole rather than to the building or utility system component to which the mitigation applied.

Finally, it was cumbersome to substitute the secondary data into the HAZUS®MH simulations, and it was not evident that this would lead to results that are more accurate, because the former are also national averages. These data were considered only in those cases where the HAZUS®MH results were beyond the extreme bounds of benefit-cost ratios.

One of the important issues discussed early in this study was the selection of an appropriate discount rate. The real rate used for discounting is based on market interest rates. The base case

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[5]A prevailing economic hypothesis, and one that has been verified in some instances, is that government expenditures do not have a full expansionary effect on the economy but are offset in part, in full, or even have contractionary effects due to inefficiency offsets. That is, government expenditures require increased taxes (and, hence, reduced consumer spending or business investment) or that government borrowing raises interest rates and reduces private investment. This may well be the case for government spending on hazard mitigation but would apply equally to continued government spending on post-disaster assistance. Part of this presumed displacement effect might be attributable to the fact that much of the product of government spending is in the form of non-market goods and services and hence does not show up in GNP accounts. In fact, some analysts have found there to be sizeable returns to government infrastructure spending because of broader societal benefits (typically externalities, or spillover effects). This, in fact, is the opposite of the displacement theory and represents a type of investment enhancement effect. Because of the controversy surrounding this consideration and the lack of definitive measures, this study omits it from analysis.

real discount rate used was 2 percent, the rate recommended by the Congressional Budget Office (1998). This rate is based on a CBO estimate of the long-term cost of borrowing for the federal government and generally is considered a conservative estimate of the long-term real market risk-free interest rate. The Office of Management and Budget (OMB) recommends that the real rate should be based on the rate of return to private investment (OMB, 1992). Sensitivity tests were performed using 0 percent as a lower bound and 7 percent as an upper bound. The 7 percent rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. This rate was generally considered an upper bound for federal projects because the rate of return for public sector projects is lower than for private sector projects. The 2005 real discount rates required by OMB are within the range of discount rates used for this study.[6] Note, again, that it is considered inappropriate to discount the economic value of avoiding future statistical deaths and nonfatal injuries, so no discount rate is applied to these benefits. This is because there is no well-established concept of the time value of life. Although the method requires a dollar value for a statistical life saved, life need not be treated as if it were interchangeable with money or is subject to all of the same processes that affect money. There are no loans for human lives, no interest payments, no life bank accounts, and there is no generally accepted principle that a life next year is worth less than a life this year.

4.2.3 Societal Impacts

Two types of societal impacts are measured in HAZUS®MH: casualties and displacement. Some modifications to the HAZUS®MH methodology were necessary to address the special needs of this study (e.g., estimation of benefits from nonstructural hazard mitigation). These are discussed below and in Appendix E.

Because societal impacts are not readily quantifiable, these impacts often are mentioned, but not analyzed in cost-benefit analyses. This project has attempted to go beyond a cursory mention of these savings to better understand the relationship, on a societal level, between impact and mitigation. Two major methodological issues required resolution because the potential societal

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[6] The rationale for the use of a market interest rate is that it is equal to the rate at which those in the economy are willing to trade present for future consumption and therefore reflects societal preferences. Market interest rates are equal to the sum of the real rate of interest (i.e., the rate of return on capital) and inflationary expectations. Most variations are due to changes in inflationary expectations because the rate of return on capital is fairly stable over time. The real rate of interest is the appropriate discount rate for benefit-cost analysis. Both the U.S. Government Accountability Office and the Congressional Budget Office use discount rates for benefit-cost analysis based on U.S. Treasury borrowing rates. U.S. Treasury bonds are virtually risk free. The maturity date typically quoted is the 10-year U.S. Treasury note, which is used as a benchmark rate by many financial institutions. The yield to maturity on the 10-year U.S. Treasury note was 4.34 percent in the week ending September 12, 2003 (Wall Street Journal, 2003).

Expected inflation, relative to historical inflation, is very difficult to measure. One of the most commonly used measures of expected inflation is the current inflation rate. The most widely used measure of the inflation rate is the Consumer Price Index (CPI) for all urban consumers. The CPI is measured monthly by the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2005). Assuming expected inflation is equal to the August 2003 CPI (2.6 percent), the real rate of risk-free interest on the 10-year Treasury note is 1.74 percent. Another estimate of the real rate of risk-free interest is the yield to maturity on a Treasury Inflation Protection Security (TIPS), which is indexed to the inflation rate measured by the CPI. Because of this indexing, the market interest rate of the TIPS is equal to the real interest rate. The TIPS that is most similar to the 10-year U.S. Treasury note matures in July 2013. The market interest rate for the 10-year TIPS is 2.23 percent (Wall Street Journal, 2003). Based on this interest rate, the market expectation for future inflation is 2.11 percent. The 2.23 percent real market interest rate incorporates market expectations about the inflation rate rather than the historical inflation rate. For simplicity, a 2 percent market interest rate was adopted for this study. The 2 percent rate is almost the midpoint between the real rate based on historic inflation and the real rate based on expected inflation.

savings of mitigation had not been modeled and some of the savings/impacts could not be quantified. The first issue stemmed directly from the difficulty of quantifying many societal impacts as little work has been done to model them. Even more problematic was that the data needed to evaluate the societal impacts and possible savings of mitigation are not routinely collected (H. John Heinz III Center for Science, Economics and the Environment, 2000). As a result, much of the quantified work on this project was limited based on the timeframe, scope of the study, and available data.

One of the major facets of this study was a focus on quantifying societal consequences of disasters so that they can be translated into dollar savings. Although this was a very limited approach, it was the only viable approach given time and financial constraints. The modeling focused primarily on how mitigation reduces casualties and associated expenses. Other aspects included reduction in displacement and associated costs. Due to the nature of the mitigation grants funded by FEMA, these costs applied only to the flood hazard mitigation activities.

4.2.3.1 Casualties

HAZUS®MH does not explicitly provide detailed societal impact due to nonstructural damage. HAZUS®MH can generate casualty estimates only for earthquakes and, even then, can model only the effect of mitigation when such efforts are structural. Other methods were developed that used engineering judgment to estimate reduction in societal consequences.

Analysis of each mitigation project determined how the protective measure reduced societal consequences. FEMA grant application files provided specific details of the projects in terms of overall project goal, number of structures, or number of replacements or retrofits. Overall, few projects reduced displacement of people and, consequently, the need for shelter. Instead, the majority of the quantifiable reduction in societal consequences was in reduction of injuries and deaths. Table 4-2 lists, by hazard, the major types of mitigation projects sampled and analyzed for this project, and how the project type reduces casualties. In addition, Appendix E summarizes the details of each casualty model developed in this study.

4.2.3.2 Casualty Models and Value of Human Life and Injuries

Translating injuries and loss of life into quantifiable dollar figures is difficult. Estimates of the value of life vary greatly ─ from $1 to $10 million depending on the agency making the assessment or the use of the value of life figure (see Porter et al., 2002, for discussion). One of the more applicable figures is from a study for the Federal Aviation Administration (1998), in which a value of $3 million per statistical death avoided is used to value the benefit of investment and regulatory decisions.

Quantifying the costs of injuries is equally problematic. Little research has focused specifically of the cost of injuries from disasters. However, the Federal Highway Administration in 1994 published a technical report, based on a 1991 Urban Institute study, which provided figures of estimated costs of injury damages in car accidents. Bringing the figures to 2002 dollars, the estimates based on injury severity are provided in Table 4-3.

This severity scale, however, does not correspond directly into the HAZUS®MH scale and, as such, has been modified for this project. Using a geometric mean approach to combine categories, minor and moderate severity costs were merged for HAZUS®MH Level 1; the serious severity level was used for HAZUS®MH Level 2; and severe and critical injuries were merged for HAZUS®MH Level 3. As discussed earlier, the Federal Aviation Administration value of human life was used to represent the HAZUS®MH Level 4 category. Based on these adjustments, Table 4-4 lists the adopted values for life and injury costs for this study.

Table 4-2 Major types of mitigation projects designed to reduce casualties by hazard

Hazard	Mitigation	Benefit
Earthquake	Variety of structural projects designed to reduce damage to buildings during an earthquake	Earthquakes have no warning, and as a result, individuals have little opportunity to take self-protective measures. Injuries, in part, result from structural damage. Reducing the potential for structural damage decreases injuries. Benefits modeled with HAZUS®MH .
Earthquake	Pendant lighting retrofit and replacement in schools; ceiling retrofit and replacement	Pendant lights and certain types of ceiling systems, particularly in schools, have the propensity to fall during earthquakes. Documented injuries are rare since most major earthquakes have occurred outside of school hours. The assumption, however, is that mitigation activities focused on pendant lights and ceiling systems will reduce the number of lights that fall in an earthquake. Benefits were modeled using engineering judgment.
Flood	Purchasing and demolishing homes in flood-prone areas	Mitigation to purchase and demolish homes in flood-prone areas reduces the potential for injuries that can result each time the structure floods. Some data in the FEMA grant applications for these mitigation projects specify that the project specifically was aimed at reducing future repeat outbreaks of hepatitis. Benefits were modeled using injury rates in other flood events as reported by the Centers for Disease Control.
Wind	Constructing tornado saferooms	Tornado threats develop relatively quickly, but there often is a short window for individuals to take protective action. These mitigation projects focus on building saferooms in public spaces or in homes to offer a safe refuge during threatening weather. Estimation of benefits used probability of tornado events in a given location in conjunction with HAZUS®MH and ATC-13 (ATC, 1985) casualty estimates.
Wind	Shelter hardening and shuttering	Evacuations from hurricanes focus on storm surge effects, not wind. Evacuations protect those in low-lying areas from potential injuries from surge. Shelter retrofitting appears to focus on bringing shelters, particularly those in Florida, to the highest level of wind resistance so that the shelters will be safer and on increasing the shelter inventory. Estimation of benefits used shelter capacity information in conjunction with injury estimates in previous hurricane events.

Table 4-3 Cost of injuries (Urban Institute, 1991)

Severity	Cost (2002 $)
Minor	6,000
Moderate	49,000
Serious	180,000
Severe	590,000
Critical	2,400,000
Fatal	3,200,000

Table 4-4 Casualty values mapped into HAZUS®MH

Severity	Cost (2002 $)
HAZUS1	17,000
HAZUS2	180,000
HAZUS3	1,200,000
HAZUS4	3,000,000

It was beyond the scope of the present study to develop and justify new, hazard-specific comprehensive costs to reflect HAZUS®MH injury levels. Thus, the Federal Aviation Administration (1998) and Federal Highway Administration (1994) figures were used. Note that these values are not limited to car crashes and that the comprehensive costs in Table 4-3 reflect medical costs, lost earnings, lost household production, emergency services, vocational rehabilitation, workplace costs, administrative, legal, pain and lost quality of life, and other factors. Medical costs alone represent a relatively small portion of the comprehensive cost, typically 10 percent or less. Further, note that the costs shown in Table 4-3 are not uncertain. They are not mean values with statistical distributions but rather discrete values chosen by the agencies of the federal government to represent the benefit associated with avoiding one such statistical death or injury. The only exercise of judgment in the present application was in the mapping from Abbreviated Injury Scale (AIS) to HAZUS®MH injury levels (see Appendix F). Note also that AIS Levels 1 through 5 each represent a range of injuries. Regardless of how the reader would value any particular injury in some AIS level, how it might be treated, or whether it should be equated with another injury in the same AIS level, the federal government assigns them the same value for use in benefit-cost analysis.

4.2.3.3 Displacement

Displacement of persons during recovery time is a fundamental social impact of disasters. HAZUS®MH provides estimates of displacement time that can be used to estimate displacement cost associated with relocation. All residential flood mitigation projects included properties with 100-year flood depths that warranted long-term displacement cost calculations. HAZUS®MH recovery times by flood depth were used to estimate displacement cost and are included in Table 4-5.

**Table 4-5 Relationship between flood
depth and recovery time in days**

Flood Depth (feet)	Recovery Time (days)
1	90
2	180
3	270
4	360
5 – 7	450
8	720

The benefits associated with displacement cost were calculated for the 100-year flood event. The benefits included rent for an apartment, furniture and other household items. Median rent by county from the U.S. Census determined rental costs. Rent for furniture and household items are a fixed $300 per month. An additional $100 per month covered an average increase in commute time. Sensitivity studies consider an overestimation of monthly displacement cost of 25 percent and an underestimation of 50 percent.

4.3 Supplemental Methodologies

During the course of this study, it was necessary to develop additional methods to supplement the HAZUS®MH loss estimation methodology and to address new types of benefits or losses. The additional methods were developed to assess:

1. Direct property loss from flood,

2. Direct property loss from tornado,

3. Business interruption loss from utility outage,

4. Environmental and historic benefits, and

5. Benefits from grants for process mitigation activities.

4.3.1 Direct Property Loss from Flood

Because HAZUS®MH (Flood) was not available in time for this study, an alternative methodology was developed and used to estimate future flood losses. The basic methodology consisted of four steps:

1. Determine property location and associated channel. Determine the latitude, longitude, elevation, floodplain, and channel center associated with each sample property. This was done by matching the property's address number range, street name, city, and state to a database and then interpolating the address number between block endpoints to estimate the location of the property. Using elevation maps and Q3 floodplain maps (digital map data available from FEMA), the property elevation, floodplain, and channel center closest to the property was then determined (see Figure 4-1). These calculations were performed using a Geographic Information System (GIS) tool.
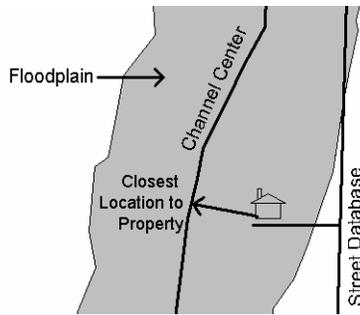
Figure 4-1 Schematic of floodplain showing how the point in the channel center closest to the property is determined.

2. Determine channel center flood depths. For each channel, the channel-center flood depths and their associated recurrence frequencies were determined. The 100-year flood depth at the channel center, denoted by d_{100}, was calculated as the elevation difference between the channel center and the elevation at a point on the edge of the 100-year floodplain, determined using Q3 digital floodplain maps and digital elevation maps. The channel center flood depth associated with other recurrence periods was then calculated using stream gauge data. Referring to Figure 4-2 A and B , if d_T denotes the channel-center flood depth associated with the *T*-year recurrence period, and g_T denotes the depth at a nearby stream gauge and associated with the *T*-year recurrence period, then d_T is estimated as $d_T = d_{100} + (g_T - g_{100})$.

A) Cross-section at USGS stream gauge   B) Cross-section at property
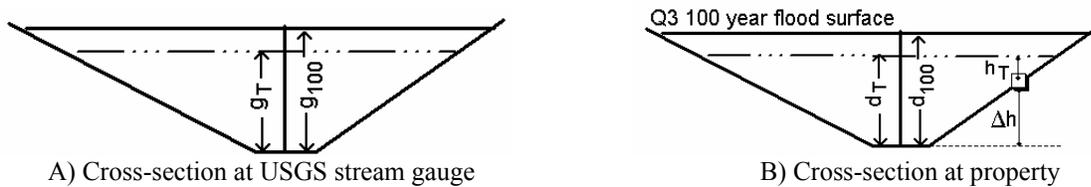
Figure 4-2 Variables used to calculate flood depths.

3. Determine flood depths at the property. This was done by subtracting from the channel center flood depth the difference in elevation between the property and the channel center. Referring to Figure 4-2B, if h_T denotes the *T*-year flood depth at the property and *Δh* denotes the elevation difference between the channel center and the property, then $h_T = d_T - \Delta h$.

4. Calculate property losses. Property characteristics such as number of stories, foundation type, presence of basements, replacement value, etc., were determined from the grant application and the National Emergency Management Information System (NEMIS) database. Damage functions that relate property loss with flood depth were taken from HAZUS®MH. These relationships were used with the property flood depths h_T to determine *T*-year flooding losses for several values of *T*. The *T*-year losses and recurrence frequency were numerically integrated to calculate the expected annualized property loss.

These four steps were performed twice: once without and once with mitigation. The difference between expected annualized loss without and with mitigation is the expected annualized benefit for property losses. A present-value calculation yields the present value of property benefits of the mitigation. Other factors that contribute to benefit, such as environmental and dislocation costs, were added to estimate the overall mitigation benefit and the benefit-cost ratio for the property.

In this study, the first step proved to be problematic, largely because of imprecise address information in the grant applications and because of discrepancies between the estimated location calculated during Step 1 and the true property locations. When mapping the estimated property locations along with the floodplains as shown in the Q3 maps it became evident that a large number of properties appeared to lie *outside* of the 100-year floodplain. (An example is shown in Figure 4-3.) This caused concern because mitigation funding rules require that the building be subject to flooding. It was not surprising, however, because geocoding errors are common. The geocoding error (defined here as the distance between the estimated and true property locations) can reach 1,000 ft in urban areas and 2.2 miles in rural areas with the true location of 1 in 100 rural properties lying more than 1,600 feet from the estimated location.

Because of this difficulty, Step 1 was modified. As described above, each property was geocoded (e.g., large dot in Figure 4-3) and associated with a floodplain (floodplain region in Figure 4-3) and channel center. It then was assumed that the "true" property location lay at some uncertain distance along the line segment between the edge of the 100-yr floodplain and the channel center, with uniform (equal) probability of lying at any given point along the line segment. As in Steps 2 through 4, losses then were calculated for each of several points along the line segment. A numerical technique called Hermite-Gauss quadrature was used to integrate losses and the probability distribution of the property location. Appendix G provides a more detailed description of this procedure.
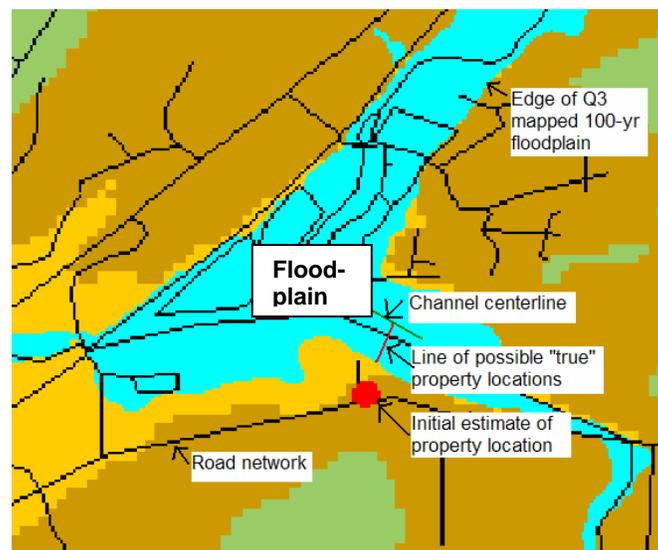
Note: The building site (large dot) is placed on the road network where it falls just outside the 100-year flood boundary. The actual location of the building is off the road network and in the floodplain.

Figure 4-3 Illustration of geocoding error in flood analysis.

4.3.2 Direct Property Loss from Tornado

One of the pilot studies for this project (Tulsa, Oklahoma) identified the need to evaluate the benefits of "saferooms" in tornadoes. HAZUS®MH currently does not address tornado hazards; therefore, an alternative method was developed. First considered were methods by Grazulis (1993) and Hart (1976). GIS data on tornado occurrences sorted by time-period and by Fujita scale rating from the Storm Prediction Center at the National Oceanic and Atmospheric Administration (NOAA) were retrieved.

The approach selected for modeling economic and societal losses in terms of number of casualties caused by tornado damage assumes that the country can be divided up into one-degree by one-degree cells that contain tornado frequency information on events that have affected that cell. To model the areas affected by these events, a degradation model was used that allows for attenuation of effects (e.g., wind speed) with longitudinal distance and width in calculating the probability of a given wind speed. To estimate losses caused by these events, HAZUS®MH damage and fragility functions were used. To estimate casualty levels, the model described above and in Appendix E was used. The overall method for estimating tornado losses is described in detail in Appendix H.

4.3.3 Business Interruption Loss from Utility Outages

FEMA mitigation grants that make electricity and water utilities more disaster-resistant are intended not only to reduce property damage but also to prevent business interruption losses. However, the ability of HAZUS®MH to estimate business interruption losses stemming from utility lifeline failures is very limited. HAZUS®MH only provides estimates of utility "downtime," which then requires external data to be translated into lost income to utilities themselves. Moreover, HAZUS®MH currently lacks the ability to calculate losses to direct and indirect utility customers. This study developed a method for calculating and business interruption losses caused by utility outage; it is described in detail in Appendix I.

The overall strategy to simulate these omitted customer losses involved performing some supplementary calculations outside HAZUS®MH and then inserting the results back into the HAZUS®MH model to exploit its ability to compute indirect losses. First, HAZUS®MH downtime results were translated into utility business interruption loss. This result was used to estimate the direct business interruption effects of a utility outage on its customers. These first round supply shortage effects were inserted into the HAZUS®MH Indirect Economic Loss Module as an entire vector of final demand changes. HAZUS®MH then internally performed flexible input-output model computations of what is now conventionally referred to as the indirect category of business interruption losses from utility service disruptions (income losses to suppliers and customers of the initial customers whose utility service is disrupted). This captures impacts on businesses that are neither directly physically damaged nor actually cut off directly from utility services but that lose income because at least one member of their supply chain or customer chain is without water or power.

4.3.4 Environmental and Historic Sites Benefits

Several nonmarket valuation methods are available for estimating the environmental and historic sites benefits of natural hazard mitigation. These methods include stated preference and revealed preference approaches. Contingent valuation, contingent behavior, and conjoint/choice analysis methods are examples of stated preference approaches. Travel cost, averting behavior, and hedonic price methods are examples of revealed preference approaches. The current state of the art in benefit estimation is to combine stated and revealed preference approaches to exploit the strengths of each approach and better deal with the weaknesses.

It is costly to use the revealed and stated preference methods. First, the travel cost and hedonic pricing methods require location-specific datasets. A single study would have been feasible in the time allotted, but the number of studies required to assess the environmental benefits of several mitigation projects, was not feasible due to time constraints. Second, using a single revealed preference method would exclude large classes of environmental values from the benefits assessment. The travel cost method focuses on recreation benefits. The hedonic price method focuses on benefits to property owners. Because mitigation projects can have recreation, property value and other environmental benefits, a focus on one valuation method could lead to large errors. Consideration of multiple revealed preference valuation methods also is costly.

When the cost of primary data collection is prohibitive, the benefit transfer approach, a specialized version of data transfer developed by environmental economists, is the wisest approach (Brookshire and Neil, 1992; Bergstrom and DeCivita, 1999). In this study, benefit estimate transfer and meta-analysis transfer methods were used. With benefit estimate transfer, researchers obtain a benefit estimate from a similar study conducted elsewhere and use it for the current policy analysis case study. Benefit estimate transfer using meta-analysis has three advantages over benefit estimate transfer alone. First, by employing a large number of studies, benefit estimates will be more rigorous (e.g., controlling for outliers[7]). Second, meta-analysis may be used to control for differences in functional form and other methodological differences across studies. Third, differences between the study site and the policy site can be better controlled.

Appendix J summarizes how the benefit transfer method was employed in this study to assess the following types of environmental and historical benefits: water quality; drinking water; outdoor recreation trips; hospitals and hazardous waste; wetlands; aesthetic, health, and safety benefits from underground power lines; and cultural and historic resources.

4.3.5 Grants for Process Mitigation Activities

The basis of measuring benefits of a process mitigation activity is whether it leads to mitigation action(s). An information campaign, for example, results in tangible benefits only if it induces behavioral changes that lead to mitigation efforts. The printing of brochures alone is not sufficient to generate benefits.

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[7] Anomalous or extreme results.

The difficulty is in establishing a causal link between the process product and subsequent action and accurately measuring that linkage. The desired measure would incorporate the change in the probability that mitigation will occur that is attributable to the process grant and not to some other source, such as a project grant. However, it is not likely that this can be accurately measured except in rare instances. The best way to determine the change in the probability might be to survey decision makers who are responsible for implementing mitigation actions; however, no such survey data that could be combined with information on process grant costs and benefits were readily available. Measurement is further complicated by several factors including the possibility that one grant for process activities may lead to another process grant before eventually leading to mitigation action. What is most easily observed are savings in damages attributable to many different sources or inputs. In addition, other factors may obscure the relationship, including the event of a major disaster and funding from non-FEMA sources.

A grant for a process activity yields a benefit primarily when it results in a "spin-off," a type of "synergistic activity" defined as a mitigation activity not directly funded by FEMA that is the direct result (an action that would have not otherwise taken place) or indirect result (an action that is accelerated in timing, but would have taken place eventually) of FEMA hazard mitigation grant support. A process that itself cannot lead to action or to a subsequent FEMA-funded project grant for project activities requires a spin-off to achieve benefits. The exceptions are economic spillovers or when the process grant involves the more effective use of the previous expenditure without incurring additional costs (e.g., brochures urging people to stay alert for existing tornado sirens).

Information on the benefits and costs of process activity grants is scant, at best. The analysis performed in this study drew heavily on similar analyses activity as only a few studies allow a direct comparison of some type of benefits to the cost of the grant (URS Group, 2001; Porter et al., 2004; Taylor et al. 1991). Thus, in each category, the benefits relative to the costs of mitigation actions (not the costs of process activity grants per se) are mainly considered.

See Appendix K for more details in the logic behind these conclusions. A wide range of studies was reviewed but, unfortunately, only a handful provided information that could be used directly in the analysis. First, the TriNet project review (see URS Group, 2001) may be used to assess the effectiveness of a process activity grant in the area of multihazard mitigation. The grant appears to be consistent with the definition of a process activity grant, and has a total cost of $16.76 million. The overall grant emphasizes improved building codes, but was funded under FEMA's hazard mitigation grant program with other features, including a plan for improved data transmission, improved spatial resolution of the geographic variation in earthquake ground motions, and improved motion sensors. This multi-faceted strategy was designed as part of an overall plan to reduce damage from earthquakes, but several features protect against other hazards (e.g., the building codes protect against landslides and strong winds, and the warning systems protect against flash floods and some man-made hazards). The impact of the grant was not only on reduced building damage but also on reductions in power outages and reduced casualties. In addition to the process grant's cost, there were projected costs of $23.1 million for replacing/retrofitting old code buildings and $12.4 million for developing codes for new buildings, or a total implementation cost of $35.5 million. The total net benefits of mitigation, excluding the process activity grant, were estimated at $37.8 million (total benefit of $73.3

million minus $35.5 million). Netting out the $16.76 million in process grant activity costs, it is immediately seen that net benefits are still positive. Put another way, the benefit-cost ratio without the process activity grant cost is 2.06. The ratio, including the grant as part of costs, falls to 1.4, but is still above one.

A flood mitigation planning study for Mecklenburg County in North Carolina also was used for multihazard mitigation analysis. This study suggested that if the county implemented new floodplain restrictions, future damage to structures could be reduced from $25 million to $8.5 million. The benefit-cost ratio associated with these new measures was estimated to be 1.25. The results of the two multihazard studies were used to establish a benefit-cost ratio of 1.25 in this category. This is a conservative estimate of the benefit-cost ratio for multihazard process grants.

For risk communication, two studies provided useful data. The first was a series of reports that addressed the cost-effectiveness of the U.S. Environmental Protection Agency's public information program that urged public testing for radon before and after real estate transactions; the second involved the use of Geographic Information System maps for communicating the risk of nearby landfill or waste disposal sites to homeowners. Based on these studies, a benefit-cost ratio of 1.2 was assumed for risk communication activities as they relate to warnings. The project investigators were unable to establish a benefit-cost ratio for risk communication activities related to public education.

The economics of building code benefits pertaining to specific structural and property changes or impacts from hurricane-force winds is discussed in Lombard (1995). She estimates benefit-cost ratios for different mitigation strategies (lateral bracing, roof covering, anchorages, etc.) for different categories of hurricanes using an equation developed for the analysis. As is the case with most studies examined, the costs cited in her dissertation are not the costs of process activity grants, and, in fact, her analyses do not relate to any grants per se. They are the *actual costs of mitigation* that arise when conforming to new building code guidelines, and the benefit-cost ratios are based on an equation she derives for this type of analysis. These benefit-cost ratios vary from less than one in some cases to benefit-cost ratios of over 60, depending on the hurricane category (1 to 5) and the mitigation strategy as well as the size of the house and initial cost per square foot of the house. Lombard (1995) concludes that most benefit-cost ratios for types of building code strategies are positive and large but that the benefit-cost ratio is smallest for lateral bracing at Hurricane Category 1 and for many of the mitigation strategies at Hurricane Category 5. There is a great range in the estimated benefit-cost ratio, depending on these key factors.

One rigorous study of building codes to protect against earthquake damage was conducted by Taylor et al. (1991). This study examined benefits and costs from implementing new codes in Utah (the Wasatch Front) and Los Angeles, California. Benefits were based on savings in property damage as well as lives saved. An average benefit-cost ratio over five types of building codes for earthquake Zone 4 in Los Angeles is 6.3. For Los Angeles, a benefit-cost ratio of 16.5 is estimated, and for the Wasatch Front, one estimate is 4.3. The Los Angeles estimate is the highest suggested benefit-cost ratio observed for process activity grants and the magnitude may reflect the fact that many of the assessed impacts compare no building codes at all to Zone 4

codes, and that assumptions were made for the number of people per square foot in buildings with new codes.

For improved building codes, another study proved useful. Porter et al. (2004) provide an analysis of the benefits associated with designing wood frame homes to be stiffer or stronger than current codes require. Benefits were measured by building losses averted, whether these were minor repair bills over time or more major reconstruction. Using simulation techniques, the authors estimated that stronger-than-required construction could be cost-effective for certain kinds of buildings in many locations.

The range in potential benefit-cost ratios that pertain to process activity grants is likely very large, reflecting uncertainty and the factors that determine them. Literature suggests that some specific building code improvements and types of hazards may lead to very large and positive benefit-cost ratios for actual mitigation and implementation (see Lombard, 1995), while for others, the benefit-cost ratio could be less than one. These are not identical to the benefit-cost ratios that would pertain to process grants that led to adoption of the building codes, but they have a relationship to them.

By averaging the available information on the lower benefit-cost ratios from the Taylor et al. (1991), Porter et al. (2004) and Lombard (1995) studies, the building code process activity grant benefit-cost ratio appears to be about 4. Therefore, a benefit-cost ratio of 4 for building code process activity grants was adopted for this study. If higher values are included, such as the Los Angeles value of 16.5 (Taylor et al., 1991), or even higher values provided by Lombard (1995), then the benefit-cost ratio could be much higher.

4.3.6 Other

In addition to the methods described above, other modifications to HAZUS®MH were made to estimate expected earthquake losses for base-isolated buildings (see Appendix L) and for flood damage caused by debris flow (see Appendix M).

4.4 Community Studies Analysis

The community studies analysis is based on a multicase study methodology that examined eight community hazard mitigation programs in depth. This analysis, as contrasted with the benefit-cost analysis of FEMA mitigation grants, permitted greater depth in evaluating hazard mitigation projects by placing them into a community context.

The methodology employed included three major components:

1. Data collection and processing,

2. Computing benefit-cost ratios and determining cost-effectiveness for activities with qualitative characteristics, and

3. Developing diagrams called "activity chronologies" to identify synergistic mitigation activities and display their temporal relationship to FEMA hazard mitigation projects.

Figure 4-4 provides an overview of the community studies methodology and makes the distinction between basic data, computational or analytical steps, and study results.

Data for the community studies were collected using techniques commonly associated with qualitative research (Patton, 2002; Phillips, 2002). Section 3.2 of this report describes the data collection process and summarizes some of the primary data collected during this phase of the study. The eight communities studied were purposively selected using quota sampling procedures. Data on these communities were collected from archival files, public reports, and both face-to-face and telephone interviews with knowledgeable persons. Structured questionnaires helped to guide the telephone interviews.
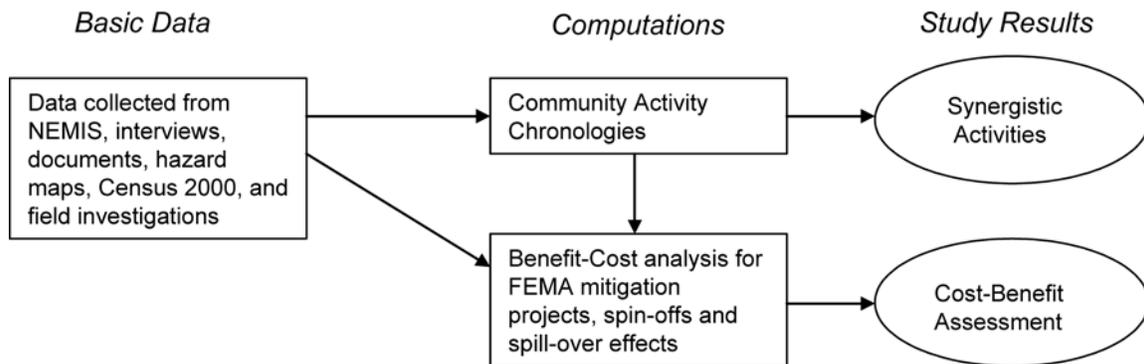
Figure 4-4 Overview of community studies methodology.

Benefit-cost analyses were performed for FEMA mitigation activities that were identified through the NEMIS database, interviews, field investigations, and project reports. When possible, the project investigators used HAZUS®MH to estimate the future benefits of specific mitigation activities. In many respects, the analysis requirements for the community studies were more extensive and demanding (compared to the benefit-cost analysis of FEMA mitigation grants), because of the diversity of projects analyzed.

4.4.1 Purposive Sampling Techniques

To provide a more nuanced and complete understanding of the benefits realized through community mitigation activities, it is not necessary that the communities reflect the distribution of the larger population of communities or that the sample allow for the evaluation of deviations from population values. Rather, the aim is to select communities with diverse characteristics to explore the variability of mitigation outcomes when viewed in a community context.

To ensure that the small number of case studies results in a rich dataset, purposive sampling techniques were used. A combination of intensity, maximum variation, and critical case sampling strategies were employed. Intensity sampling strategies focus on selecting cases that provide rich, in-depth data but that are not highly unusual. Maximum variation sampling yields cases that vary on selected dimensions of interest. A critical case sampling strategy helps to select cases that provide the most information and have the greatest impact on the development of knowledge. Use of a combination of strategies permits triangulation, flexibility, and meets multiple needs.

Purposive sampling techniques involve the use of sound judgment and an appropriate strategy to select cases such that the chosen sample is satisfactory given the objectives of the study (Hoyle, Harris and Judd, 2002). Given that only a small number of case studies were conducted, no selection procedure could ensure inclusion of all the diverse elements inherent in the population. Furthermore, random sampling procedures, which would maximize the probability that the sample communities represented the population from which they were drawn, were prohibited because the sample population was too small. In this study, purposive sampling techniques were combined with quota sampling to help ensure that the selected sample was sufficiently diverse in terms of theoretically relevant community attributes. Theoretically relevant attributes included: size of the community; type of hazard it may be subject to; number of grants received and whether both project and process grants have been awarded; geographic distribution of the communities selected; whether the jurisdiction is a city, town, borough, parish, or county; and various socioeconomic and societal structure characteristics of the community. In selecting communities, the project investigators also examined the characteristics of the community as a whole, and not just segments that may have been affected by a recent disaster.

Of greatest concern was to ensure that the range of hazards and the levels of exposure to each hazard were adequately represented among the selected communities. Quota sampling methods (analogous to stratified sampling methods in probabilistic designs) were used to ensure diverse representation of the types and levels of hazard.

For sampling purposes, a "universe" was defined as "all the people or entities that meet the designated criteria" and a population was defined as "all the people or entities that can be located, identified, or listed as being in the universe" (Bourque and Fielder, 2003, p. 178). For the selection of communities, the universe was defined as all communities that received an award from FEMA under the Hazard Mitigation Grant Program, Project Impact, or the Flood Mitigation Assistance Program. To arrive at the population, the project investigators used the NEMIS dataset as described in Section 3.1.1.

The project investigators applied a set of eligibility criteria to narrow the data available in the NEMIS database so that a sample of communities could be selected. Specific selection criteria were based on: guidelines presented in the MMC (2002, pp. 22-23) in the plan for the study; literature reviews; findings from the pilot study performed in Tulsa, Oklahoma; and discussions with the project review committees for this study. To be eligible for selection for this study, the communities had to meet the following criteria:

1. Received awards from FEMA where the objective was to mitigate damage from earthquakes, flood, or wind (coastal storm, hurricane, severe storm, tornado, typhoon);

2. Be at high or medium risk of earthquakes, floods, or wind hazard(s);

3. Be a single jurisdiction identified with a legal title as a city, town, borough, village, or county within one of the 50 states;

4. Received grants for both project and process mitigation activities (including Project Impact);

5. Received grants that total greater than or equal to $500,000;

6. Received a total of no more than 15 grants; and

7. Completed at least one mitigation grant before this study was initiated.

Table 4-6 identifies the list of eight communities studied. Originally, 10 communities, including Mandeville, Louisiana, and Ft. Walton Beach, Florida, were selected for inclusion in the community studies. During the last half of 2004, however, significant hurricanes (Charley and Ivan) affected Florida and the Gulf Coast. Because of demands placed on FEMA staff and local and regional emergency officials in response to these hurricanes, conducting field visits or interviews and collecting much of the basic information needed to establish the key parameters for two originally selected communities (Mandeville, Louisiana, and Ft. Walton Beach, Florida) would have been impossible, these two communities were dropped from the analysis.

Table 4-6 Communities selected for analysis

Community Hazard	Small Communities (Population 10,000-49,999)	Medium Communities (Population 50,000-499,999)	Large Communities (Population > 500,000)
Earthquake only		Hayward, California (in FEMA Region IX) Orange, California (in FEMA Region IX)	
Flood only	Jamestown, North Dakota (in Region VIII)		Multnomah County, Oregon (in FEMA Region X)
Flood and wind	Freeport, New York (in FEMA Region II)	Tuscola County, Michigan (in FEMA Region V)	Jefferson County, Alabama (in FEMA Region IV)
Flood, earthquake, and wind		Horry County, South Carolina (in FEMA Region IV)	

4.4.2 Field Research

There were five main goals of the field visits:

1. Collect relevant reports on past, ongoing and future mitigation activities,
2. Identify knowledgeable people for telephone and face-to-face interviews,
3. Conduct both formal and informal interviews with knowledgeable people,
4. Perform follow-up inquiries to fill in missing information or data, and
5. Perform site visits of key mitigation projects.

Table 4-7 provides an outline of the types of reports that were sought during each field visit. Depending on the location (FEMA regional office, state hazard mitigation office, or local jurisdiction), different documents were sought. In general, similar documents were available at the FEMA regional offices and the state hazard mitigation office (see discussion in Section 3.1.2). The more detailed summaries of mitigation projects were generally available at the local office of the jurisdiction that received the grant.

Table 4-7 Typical search protocol for community studies

Agency	Documents
National	
FEMA Regional Office	1. Section 404 administrative documents 2. Section 404 application instructions 3. Section 404 completed applications of subgrantees 4. FEMA mitigation policy 5. Access to NEMIS database 6. Post-disaster studies
U.S. Army Corps of Engineers, Division Office	1. River basin plans 2. After-action studies 3. Status reports, Section 205 studies 4. Rehabilitation studies of damaged Corps facilities
State	
Emergency Management Office	1. Section 409 hazard mitigation plans 2. Section 404 administrative documents 3. Section 404 application instructions 4. Section 404 completed applications of subgrantees 5. Reports including benefit-cost calculations/procedures 6. Flood maps 7. Interagency hazard mitigation team reports for prior and subsequent disasters
Governor's Office	1. Executive Orders 2. Applications for disaster declaration 3. Correspondence with FEMA and communities 4. Blue Ribbon Investigative Commission reports 5. Reports from Cabinet or other state agencies
Community affairs/housing	1. Buyouts and elevations (floods) 2. Damage assessments 3. Reconstruction plans 4. Section 404 administrative documents 5. Section 404 application instructions 6. Section 404 completed applications of subgrantees 7. Community Development Bloc Grant post-disaster applicant manuals
Planning	1. Regional Plans
Health	1. Post-disaster mortality and morbidity statistics 2. Post-disaster studies 3. Mutual aid agreements
Natural resources/environment	1. Post-disaster studies 2. Earthquake and wind maps 3. Historic preservation policies and guidelines for rehabilitation
Emergency Management Office	1. Section 404 administrative documents 2. Section 404 application instructions 3. Section 404 completed applications of subgrantees 4. Reports, including benefit-cost calculations/procedures 5. Project Impact materials

Agency	Documents
Mayor's office and city council	1. Organizational charts 2. Agendas and minutes of meetings 3. Local legislation
Building and safety	1. Damage estimates 2. Inspection protocols 3. Building permits 4. Buyout and elevation records (floods)
Planning	1. Planning studies 2. Zoning regulations 3. Redevelopment plans
Housing	1. HUD applications and awards 2. Section 404 completed applications 3. Reports including benefit-cost calculations/procedures
Health	1. Protocols for first responders 2. Emergency response plans
Public works	1. Buyout and elevation records (floods) 2. Infrastructure damage reports 3. Mitigation policies

The field research program generally proceeded in four main steps:

1. Obtain relevant reports prior to field visit. Upon selecting a particular community for analysis, the NEMIS database was used to identify all FEMA hazard mitigation awards to the community. In addition, basic demographic information about the community was also collected. Where possible, information on state laws pertaining to natural hazards mitigation that are enforced locally, and local natural hazards regulations and ordinances, were sought. Much of this information was available through the Internet.

2. Obtain relevant reports during site visits to FEMA regional offices. The goals of this step were to establish working relationships with FEMA Hazard Mitigation Officers and elicit their cooperation in gathering data for the study; become intimately familiar with the Hazard Mitigation Grant Program (HMGP), Project Impact, the Flood Mitigation Assistance Program (FMA), and synergistic activities associated with the community; and gather names and contact information of community mitigation leaders who would be contacted in the next step.

3. Obtain reports during community field visit. This step took place in the community itself. By this time, the overall community hazard mitigation program was understood, but only limited information had been gathered on early activities and details. Therefore, the goals at this stage were to develop a comprehensive understanding of how the community had dealt with its natural hazard risks over time, to explain the benefits and costs associated with the individual mitigation programs, and to explain the synergistic effects provided by the total of all their mitigation activities. The data collected were needed to determine quantitatively if mitigation has been cost-beneficial and the qualitative nature and benefits of synergistic activities.

4. Follow-up inquiries. The goal of this step was to complete the data collection effort. After returning from the community, field researchers completed a preliminary study

report that contained a summary of the information that had been collected to this point and a list of data still needed. The field investigators also consulted with project economists to see if additional data were needed to complete the economic analyses. This summary includes a list of the probable locations of any desired data as well as contact information for individuals who can be asked whether the data were available. Inquiries were generally made by telephone or e-mail.

4.4.3 Interview Guides

To standardize the telephone interview process, an interview guide was developed, tested and used. This interview guide was initially tested during the pilot study in Tulsa, Oklahoma. The guide consisted of several different parts: basic information about the person being interviewed, the interviewees' knowledge of existing hazard mitigation regulations or laws, their knowledge of current natural hazard risks, their knowledge of community hazard mitigation activities, their knowledge of specific FEMA-sponsored mitigation activities and their effectiveness, their knowledge of any partnerships that were key in affecting mitigation for the community, and referral information for other contacts. The specifications for this guide, as well as the guide itself, are part of Appendix B.

4.4.4 Benefit-Cost Analysis for Community Studies

A benefit-cost analysis was performed on all FEMA-funded activities identified in the community studies analysis. The basic principles for this analysis were discussed in Section 2.1 of this report. Unlike the benefit-cost analysis of FEMA mitigation grants, which assessed the indirect benefits of mitigation, the community studies concentrated mostly on quantifying the direct benefits of mitigation (i.e., expected reductions in damage or repair costs). Indirect effects in the form of synergistic activities, however, were identified and discussed as part of the community analysis.

4.5 Methodology for Benefit-Cost Analysis of FEMA Mitigation Grants

The benefit-cost analysis of FEMA mitigation grants was comprised of four major steps. In Step 1, a stratified sample of FEMA mitigation grants was created. A "stratified sample" consists of individual grants for detailed analysis, i.e., for which all applicable project-specific benefits were calculated. The sample was stratified by hazard type (earthquake, wind and flood) and mitigation type (project and process activities), for a total of six strata. In Step 2, the benefit-cost ratio for an individual project within a stratum was calculated. In Step 3, the benefits and costs from the sample were scaled up to the entire population of project and process activities. Finally, in Step 4 the future savings to the federal treasury were estimated. These steps are discussed in Sections 4.5.1, 4.5.2, 4.5.3, and 4.5.4 below. Section 4.5.5 provides a discussion on issues affecting uncertainty and its quantification.

4.5.1 Stratified Sample

The population of all grants was first stratified (grouped) by hazard (flood, wind, or earthquake) and mitigation activity type (project or process). Thus, one such stratum (or group) contains only flood-related, project mitigation activities. Another contains only flood-related, process

mitigation activities. The reason for stratifying in this way is that benefit-cost ratios may differ among these broad categories of mitigation grants, and the project investigators wanted to ensure that several activities in each stratum were represented in the sample.

Mitigation activities within a stratum do not contribute equally either to total benefit or to total cost. It is likely that a small number of costly activities dominate both cost and benefit. To ensure reasonable results, this fact should be reflected in the sample. Furthermore, it is desirable that activities of all cost levels were present in the sample. Therefore, mitigation activities within each stratum were sorted in decreasing cost. They were binned (grouped in batches of similar cost) so that the total cost of bins were approximately equal ─ a smaller number of costly mitigation activities in the higher-cost bins, a larger number of lower-cost mitigation activities in the lower-cost bins. One mitigation activity was then selected at random from each bin. As a result, the sample contains more grants for high-cost mitigation activities than for low-cost ones, and yet still contains at least some grants for low- and medium-cost activities. Mathematical tests were performed to confirm that this approach produces more accurate estimates for the population benefit with less uncertainty than any of several competing alternatives.

The sample included 89 grants for project activities, costing $458 million (in 2004 constant dollars), and 47 grants for process activities, costing $114 million. Table 4-8 summarizes the distribution of these grants among various types.

Table 4-8 Distribution of grants in the stratified sample

	Project Type Code	Mitigation Activity Type Description	% by No.	% by Cost
Project Activities	200.1-204.4	Acquire, Relocate, Elevate, or Floodproof Property	23	16
	205.3-205.4	Nonstructural Retrofitting/Rehabilitating – Seismic	8	24
	205.5-205.6	Structural Retrofitting/Rehabilitating – Seismic	16	48
	205.7-205.8	Retrofitting Structures – Wind	34	6
	206.1-206.2	Safe Room (Tornado and Severe Wind Shelter)	13	3
	300.1-405.1	Shoreline, Wetlands, Utilities, Flood Mgt, Roads, Bridges	5	1
	500.1-501.1	Flood Control - Major Structural Projects	0	0
	600.1-602.1	Warning Systems, Generators, and Other Equipment	1	2
		Grants for Project Mitigation Activities Total	100%	100%
Process Activities	90.4, 91.1	Mitigation Plan – Local Multihazard Mitigation Plan	25	6
	90.6, 92.1	Mitigation Plan – State Multihazard Mitigation Plan	9	11
	100.1	Public Awareness and Education	13	10
	101.1	Professional Education (Inspectors, Architects, etc.)	2	2
	103.1	Feasibility, Engineering and Design Studies	11	4
	104.1	Codes, Standards, Ordinances and Regulations	19	21
	105.1	Applied R&D in the Building Sciences	6	14
	106.1	Other Non Construction (Regular Project Only)	4	1
	106.2	Project Impact	0	0
	600.1	Warning Systems	9	4
	800.1	Miscellaneous	2	27
		Grants for Process Mitigation Activities Total	100%	100%

The reader should not expect the fraction of samples in each project category to approximate the fraction of grants in the NEMIS database because of the stratified sampling technique. The upper

portion of the table details grants for project-type activities, the lower portion, grants for process-type activities. It shows that the dominant sample grants for project activities involve retrofitting of structures for earthquake or wind, or flood acquisitions or floodproofing. The sample of grants for process activities is dominated by multihazard mitigation plans, codes and standards, and public awareness efforts. Project Impact grants are not assessed, owing to the lack of available final project data.

4.5.2 Calculating Benefit-Cost Ratios for Sample Activities

The total benefit and total cost for each project mitigation activity in the sample was calculated using the following procedure. First, the location, value, facility type, and functional characteristics (such as use and number of occupants) of each facility in a sample project were tabulated from the NEMIS database and from a reading of the grant application documents on file at FEMA regional offices. In many cases, more than one property (more than one building, for example) is affected by a mitigation grant. In such cases, as many properties within a project were examined as possible.

Next, the hazard function at each property site was calculated. The "hazard function" is defined by the frequency with which the property experiences various levels of excitation, where excitation could mean ground shaking intensity for earthquake grants, wind speed for hurricane or tornado mitigation grants, or flood depth for flood-mitigation grants. Different methods were used to calculate hazard potential for each hazard type.

Next, vulnerability functions were applied to each property at each level of excitation, once for pre-mitigation conditions, and once for post-mitigation conditions. A vulnerability function relates economic or human loss to the hazard excitation level, given the value, facility type, and functional characteristics of the facility. The expected annualized loss for each property, pre- and post-mitigation, were then calculated as the integral of loss conditioned on excitation and the absolute value of the first derivative of the hazard function. The difference between the annualized loss, pre- and post-mitigation, is taken as the annualized benefit of mitigation for that property.

Finally, the present value of the annualized benefit for these sampled properties was calculated and divided by the present value of the cost of the mitigation efforts. The result was taken to be the benefit-cost ratio for the project. The benefit-cost ratio for process mitigation activities was calculated in a different fashion, as discussed in Section 4.3.5.

4.5.3 Extrapolating Benefits and Costs from Sample to Population

The benefits and costs associated with each sampled grant were calculated. The ratio of the former to the latter is the benefit-cost ratio for the grant. The average of these figures is taken as the benefit-cost ratio for the stratum sample. Recall that each stratum contains a number of grants that were not sampled and whose benefit is unknown. However, their costs are known. The total cost of the stratum (sampled and not sampled) was multiplied by the benefit-cost ratio for the stratum sample. The product is the estimated benefit for the entire stratum, including grants that were included in the sample and those that were not. The sum of the estimated benefits for all strata is the total estimated benefit of the population of grants (referred to as the

estimated population benefit). The sum of the costs for all strata is the total cost of the population of grants (population cost). The ratio of the estimated population benefit to population cost is the population benefit-cost ratio.

Such a sampling approach produces some uncertainty regarding the true population benefit-cost ratio. A series of statistical tests was performed to estimate the degree of systematic error and uncertainty produced by this approach (see Appendix N for details on different methods investigated for scaling sample results to the population). It was found that this approach produced an average error of the benefit-cost ratio of less than 0.03, with a standard deviation of error of 0.39, where error is defined as the difference between estimated and true population benefit, as a fraction of true population benefit.

4.5.4 Potential Future Savings to the Federal Treasury

For the most part, the methodological procedures described previously are based on the standard benefit-cost analysis approach. The cost of FEMA mitigation programs, plus mitigation expenditures by any other entity (typically state or local government), is compared to the benefits to society as a whole (avoided losses to private and public sectors).

In contrast, future net savings to the federal treasury because of FEMA hazard mitigation programs differ from net benefits to society in the following ways:

1. Costs: Only FEMA expenditures (about 75 percent of the total eligible project costs, which exclude state and local government matching) were considered.

2. Savings: Savings are not the same as total benefits to society, but rather include only:

   a. Reduced future federal government spending by various agencies for recovery and future mitigation.

   b. Avoided federal tax revenue losses because of reduced individual and business income tax casualty[8] loss deductions and increased individual income tax payments from the continued earnings of those who were not injured or killed.

Table 4-9 lists categories of federal expenditures that can be reduced by implementing hazard mitigation activities. Table 4-9 also includes the source of data used to estimate each category.[9]

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[8]Casualty loss in this section refers to the tax code definition of the term — property damage — in contrast to its use elsewhere in this report, which refers to deaths and injuries.

[9] The National Flood Insurance Program is not included because it is actuarially sound, i.e., payouts are equivalent to premiums in the long run. Also, HUD Community Bloc Grants are not listed because data could not be obtained on the percentage of these grants devoted to hazard mitigation. A rough calculation that these funds are applied to cover 40 percent of the 25 percent local match to FEMA hazard mitigation grants yields an estimate that is less than 1.0 percent of the total of savings in the other categories listed in Table 4-9 (see also Section 6). Finally, the Small Business Administration (SBA) savings listed in Table 4-10 do not include the cost to the federal government of the actual loan subsidies. This transfer would amount to the differential between the market interest rate and the SBA loan rate. This may be small in today's market, but is likely to be more significant when interest rates increase. Unfortunately, there is no accurate way to measure this interest rate differential and the associated transfer.

Table 4-9 Federal government relief and mitigation categories

Category	Source of Data
Public assistance	FEMA (2005)
Individual assistance/human services	FEMA (2005)
Mission assignments/standby grants	FEMA (2005)
FEMA administrative costs	FEMA (2005)
Mitigation expenses	FEMA (2005)
SBA default and cost of administration	SBA (2005)
U.S. Army Corps of Engineers emergency measures	USACE (2005)

Table 4-10 lists categories of avoided federal tax revenue losses, their base, and their source. For this study, corporate tax revenue savings are a small category because the vast majority of FEMA mitigation grants go to public entities rather than private businesses. The notable exceptions are some private hospitals and private electric and water utilities. Similarly, individual casualty losses influenced by FEMA hazard mitigation grants are also limited, in this case to the subset of flood mitigation (primarily to buyouts of flood-prone homes).

Table 4-10 Federal tax revenue categories affected by hazard mitigation

Category	Base	Source of Data
Individual casualty loss deduction	Residential property[a]	This study
Individual income tax payments related to reduction in injury and death	Death and injury	This study
Corporate income tax payments related to reduction in casualty loss and business interruption	Property and business interruption[b]	This study

[a] Applied to uninsured household property damage following deduction of 10 percent of average adjusted gross income.

[b] Applied to uninsured property and business interruption losses of tax-paying entities only.

The analysis assumes that government assistance will decrease in proportion to decreases in "commonly measured" natural hazard losses.[10] While some might argue that government agencies have a target level of expenditures regardless of conditions, this analysis assumes that these agencies behave rationally in light of their objectives. This means that if hazard losses were reduced, the funds devoted to them would be reduced in the long run. In the short run, of course, if hazard mitigation more than pays for itself, it would represent a public "investment" opportunity worthy of at least a continuation of base spending until some overall level of hazard loss reduction is attained. These considerations are the reason why the term "potential" is

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[10]"Commonly measured" losses are those visible to providers of post-disaster funds (property damage and casualties), but exclude categories like business interruption, environmental, historical, societal, and administrative cost.

applied to the savings measured ─ the savings represent a justification for reduced public spending on post-disaster recovery, but whether the reduction is actually realized depends on several considerations. Nevertheless, hazard recovery needs are definitely reduced.[11]
The estimate of total avoided losses from annual average mitigation in this study is $1.4 billion, and the "commonly measured" avoided losses due to property damage and casualties are $1.32 billion.[12] The latter represents 17.4 percent of average annual hazard losses in the U.S. over the period 1993-2000, or $7.6 billion (University of South Carolina, 2005).[13,14] Hence, the base used in the estimation of savings to the federal treasury is 17.4 percent of the various federal payments listed in Table 4-10.

The 17.4 percent figure reflects the fact that mitigation projects have long useful lives (assumed to be 50 years for most structures in this study). Thus, the 17.4 percent represents benefits of mitigation initiated in a given year, but realized in each of the next 50 years (the present value of all the future savings). These savings were compared to total (unmitigated) hazard losses in a single year. This comparison is appropriate because, in the absence of the mitigation, the losses would have otherwise continued for an average of 50 years.

Finally, given the difficulty of projecting future benefits of hazard mitigation, the continuation of current conditions with regard to various federal assistance rates, tax rates, base philanthropic giving rates, and insurance coverage is assumed, as is a constant proportional relationship between mitigated loss and overall disaster loss trends.

The methodology described above applies only to grants for project mitigation activities. It is modified for grants for process mitigation activities because the estimation of benefits of process mitigation activity grants does not result in separate estimates for individual components such as property damage and casualties. Process mitigation activity grant benefit components were assumed to be in the same proportion as project mitigation activity grant components. Total benefits per dollar of expenditure will still differ between project and process activity grants.

4.5.5 Analyzing Model Sensitivity and Uncertainty

Many of the parameters of the mitigation effort are imperfectly known, as are many of the parameters used to model the resulting benefit. These imperfectly known parameters are referred to as uncertainties, and can include the site characteristics of affected facilities: soil type; facilities' physical aspects, such as the code design level; or their social and economic features, such as the facilities' number of occupants. Uncertainties for process mitigation activities can

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[11] Individual and corporate philanthropy for hazard recovery generates a tax deduction. One viewpoint is that reducing hazard damages would reduce philanthropy and hence the deduction, thereby providing additional savings to the federal treasury. However, most experts in the area suggest that individuals and corporations have a fixed target of "giving," which is not affected much by marginal changes in perceived philanthropic need.

[12] The annual average losses are one-tenth of the total avoided losses for the ten years of mitigation grants estimated in this chapter.

[13] This total relates only to hazards directly related to earthquake, wind (including severe storm), and floods. It excludes lightning strikes, wildfires, droughts, etc.

[14] Viewed another way, the average annual losses reduced in a given year are $42 million, or only about 0.55 percent of the average annual hazard property losses in the U.S ($7.6 billion). At the same time, every dollar of losses avoided in a given year is accompanied by a present value of $31.42 of losses avoided over a 50-year period. Hence, $31.42 x $42 million = $1.32 billion; and $1.32 billion divided by $7.6 billion = .174, or 17.4 percent).

include the number of people influenced (e.g., by a public-information campaign) and the material impact of the process (e.g., the degree to which a code change actually improves building performance). Sensitivity analyses quantify the effect that these input uncertainties have on the final calculations. An example would include how uncertainty in site-soil classifications affects the total benefit of earthquake project grants.

These input uncertainties propagate through the analysis and cause the estimate of the total mitigation benefit to be imperfectly known. The challenge was to estimate the mean value of total benefit and, perhaps, a measure of its uncertainty, such as the standard deviation considering the variability of the input uncertainties. To address that challenge, the project investigators used a procedure discussed by Rosenblueth (1975), Julier et al. (2000), Julier and Uhlmann (2002), and Julier (2002). In brief, one first identifies the input parameters that are uncertain and will most likely have the greatest effect on the variability of the output parameter (generally, benefit). This decision is made using expert judgment. Next, one estimates the mean and standard deviation of these input uncertainties, and quantifies their expected value and upper- and lower-bound values (in particular, $m \pm 1.73s$, where m equals the expected value and s equals the standard deviation). In many cases, these bounds are determined using expert judgment. A series of calculations are then performed that test both the sensitivity of the overall benefit to the uncertain inputs, and that can be used to estimate the mean, standard deviation, and other statistical features (skewness, kurtosis, etc.) of the total benefit. See the Rosenblueth and Julier publications noted above, as well as Porter, Beck, and Shaikhutdinov (2002) for details. To gain a better understanding of the impact these uncertainties had on the final results, various sensitivity or parametric studies were performed. For those parameters for which sensitivity studies were employed, Table 4-11 lists the benefit categories considered, the hazard that the mitigation measure was designed to offset, and the lower and upper bounds used to test the variability of the results.

The credibility of results was assessed by examining more closely those mitigation activities that produced extreme values of benefit-cost ratio, either very low or very high. Very low values suggest the possibility that the project investigators overlooked a benefit that appeared relevant to the applicant and to FEMA. Very high values suggest either a higher cost-share than was tabulated in the FEMA database or an overly optimistic assessment of benefit by the project investigators.

Table 4-11 Sensitivity parameters for project mitigation activities

Benefit Category and Variable	Hazard	Lower Bound	Expected Value	Upper Bound
Direct property damage [a]				
Site classification	Earthquake	-1 class	Mapped value[b]	+1 class
Location of the house	Flood	$0.113d_{100}$	$0.5d_{100}$	$0.887d_{10}$
Flood depth	Flood	-50%	Estimated value	+50%
Roughness	Wind	Open	Estimated value	Trees
Indirect business interruption:				
Unemployment rate	All	2.6%	Actual value	13.1%
Environmental/historical [c]				
Relevant population	All	-50%	Estimated value	+40%
Duration of loss	All	-75%	Estimated value	+100%
Casualty				
Value of injuries/death	All	-50%	Estimated value	+50%
Number of occupants	Earthquake and Wind	-75%	Estimated value	+75%
Injury rate % of shelter capacity	Wind (Hurricane)	0.2%	.55%	.9%
Injury rate % of population	Flood	6.375%	12.75%	25.5%
Homeless				
% population using shelters	Flood	-25%	Estimated value	+50%
Cost of sheltering	Flood	-50%	Estimated value	+50%
General Considerations				
Discount Rate	All except casualty	0%	2%	7%

[a] Variables listed under "direct property damage" also affect other categories.
[b] California Geological Survey (Wills et al., 2000).
[c] Sample of several sensitivity parameters for these categories.

Chapter 5
COMMUNITY STUDIES RESULTS

The chapter presents the results of the community studies. These studies were based on a comprehensive analysis of hazard mitigation activities undertaken by eight purposively sampled communities using the methods described in Chapter 4 and Appendix O. First, each community is briefly described. Second, the results of benefit-cost calculations for grants awarded by FEMA (Hazard Mitigation Grant Program, Flood Mitigation Assistance, Project Impact) undertaken by each community are presented. Cost-effectiveness results for grants awarded for process activities are also discussed. Finally, the development of a comprehensiveness factor is presented.

5.1 Sample Communities

Eight communities were selected using purposive sampling techniques (see Section 4.4.1) to represent the characteristics of communities that had received grants from FEMA for mitigation activities.

The National Emergency Management Information System (NEMIS) data file received on July 23, 2003, was used to identify the population from which the communities were selected. To be eligible for consideration, communities had to:

1. Have received grants from FEMA whose objective was to mitigate damage from earthquakes, flood, or wind (coastal storm, hurricane, severe storm, tornado, typhoon).

2. Be at high risk for earthquakes, flood, or wind hazard(s).

3. Be a single jurisdiction identified with a legal title as a city, town, borough, village or county within one of the 50 states.

4. Have both project and process (includes Project Impact) activities funded.

5. Have received FEMA grants that totaled at least $500,000.

6. Have received no more than 15 grants.

One hundred thirteen (113) communities met Criteria 1 and 3 through 6, but only 76 communities were at high risk of at least one hazard.

Communities were sorted and quota limits were set to maximize the probability that the communities selected for study varied in: (1) the combination of grants they had received from FEMA (earthquake only, wind only, flood only, earthquake and flood, wind and flood, earthquake, wind and flood); (2) whether they were at high risk of earthquake, flood, and/or wind; (3) community population (10,000-49,999; 50,000-499,999; 500,000 and over); and (4) FEMA region. Information about the 76 eligible communities was written on pieces of paper. The 76 pieces of paper were placed in a basket, shaken up, and the first community was drawn. The process was repeated until all communities were drawn. The papers were shuffled between each

draw. Once a community was drawn and either accepted or rejected for inclusion in the sample, it was permanently removed from the pool of eligible communities. Appendix O presents the details of the community selection process.

Data were collected in four phases: pre-interview activities; formal telephone interviews; field visits; and data or information processing. Pre-interview activities included the collection of documents, reports, and other data that could be used both in benefit-cost analysis and in identifying knowledgeable persons to interview in each community. Persons identified in each community were interviewed by telephone using a standardized interview guide. Respondents were asked about existing hazard mitigation regulations or laws, their knowledge of current natural hazard risks, their knowledge of community hazard mitigation activities, their knowledge of specific FEMA-sponsored mitigation activities and their effectiveness, their knowledge of any partnerships that were key in affecting mitigation for the community, and referral information for other knowledgeable persons in the community. The specifications for the interview guide and the guide itself are part of Appendix B.

Documents or written records for each community were collected from four locations: the FEMA Regional Office, the state emergency management office, in the community during field investigations, and on the Internet. The list of all documents collected and referenced can be found in Appendix P.

For each community, the first documents collected were the Hazard Mitigation Grant Program (HMGP) grant, Flood Mitigation Assistance grant, and Project Impact grant files listed in National Emergency Management Information System (NEMIS) at the FEMA Regional Office. Similar files were collected at the state emergency management office with the expectation that there would be overlap but that some unique items not found in the federal files would be found in the state files. After two community studies, it was determined that the files at the FEMA Regional Office and the state emergency management office were virtually identical and subsequent searches at the state emergency management office were foregone. (See Sections 3.1.2, 3.1.3, and 3.1.4 for the description of the contents of a mitigation grant file.)

Field investigations took place after telephone interviews had been completed and the mitigation grant and Project Impact files had been reviewed. Field investigations had two goals: to find information needed to complete computational analyses and to conduct a broader search for information, independent of information contained in the federal and regional files or gathered in telephone interviews. The focus was on collecting written documents, compact discs, videos, and other records rather than opinions and perceptions. (See Section 4.4.2 for a discussion of field research elements.)

Searches on the Internet were conducted throughout the community studies to locate documents, to prepare questions during field investigations, and to find information that could not be located in the field.

5.2 Community Descriptions

The following sections provide a summary of the communities examined in this study:

1. Freeport, New York;

2. Hayward, California;
3. Horry County, South Carolina;
4. Jamestown, North Dakota;
5. Jefferson County, Alabama;
6. Multnomah County, Oregon;
7. City of Orange, California; and
8. Tuscola County, Michigan.

Community summaries track project decisions and activities chronologically and use the descriptions provided in local documents and comments by interviewees to present the community stories as faithfully as possible. Each community summary contains four parts: a background statement with a description of the community, its risk of natural disasters, historical decisions concerning hazard mitigation, and hazard mitigation activities that preceded FEMA hazard mitigation grants; a list and discussion of FEMA hazard mitigation grants; a discussion of Project Impact if the community had received a Project Impact grant; and an activity chronology to illustrate the temporal relationship of hazard mitigation decisions and activities included in the previous three parts. The activity chronology diagram is generally constructed in two dimensions, i.e., an *x*-axis and a *y*-axis. The vertical axis (*y*-axis) is comprised of those factors or elements that generally characterize hazard mitigation programs. They consist of community participation plans, capacity building, ordinances and regulations, other state and federal grants and programs, FEMA grants and programs, and state laws. The pilot study in Tulsa, Oklahoma helped to refine the selection of these elements; leaders in Tulsa expressed a belief that "improved maintenance, continuing capital projects, stringent regulations, and aggressive citizen awareness programs" were the ingredients of a community program that would lead to a reduction in future flood losses (City of Tulsa 2002, Chapter 2, page 7). The horizontal axis of an activity chronology diagram illustrates the chronological relationship between the start of grants for project mitigation activities or process mitigation activities funded by FEMA and community mitigation activities. This visualization provides a simple means of determining if there is a potential causal relationship between FEMA grants and synergistic community activities.

5.2.1 Freeport, New York

The Village of Freeport is located on the southern shore of Long Island in Nassau County, New York, approximately 13 miles east of John F. Kennedy Airport. It was first settled in 1659 but was not incorporated as a village until 1892.[15] In 1892, Freeport was a rural community with a population of 1,821; by 1967, on its 75th anniversary, Freeport "was a thriving business and industrial community with an estimated population of 42,000," roughly its current population of 43,783 according to the 2000 Census.[16] From the start, Freeport relied on its waterfront location; it began as a fishing port and now is the recreational boating center of Long Island.

Originally, coastal Freeport was a low meadowland or wetlands, essentially a combination of a saltwater marsh and farmland that flooded regularly at high tides and during storms. Developers purchased the land from the farmers in the late 1890s and dug several canals "using the dredged-

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[15] Historical information used in this description was taken from the *Freeport Diamond Jubilee Commemorative Booklet 1892 – 1967* published by the Village of Freeport in September 1967.

[16] Ibid., p. 3.

out earth to fill the low meadowlands."[17] The first canal, dug in 1898, was the commercial Woodcleft Canal fronted by Woodcleft Avenue, now referred to as the Nautical Mile because its length is exactly a nautical mile.

As mentioned during many interviews, the canal digging operation left two legacies. First, the canals were not dug deeply enough to provide sufficient draft for newer commercial ships. Second, insufficient earth from dredging was used to fill the wetlands, thereby not eliminating the regular flooding that occurred during high tides and storms. The latter consequence did not bother the first residents, fishermen, who constructed houses on the marshland. As quoted in 1998, the superintendent of public works for the village stated, the fishermen "wanted to be right on the water, and, if that water flowed in their front door and out their back door every so often, they didn't mind so much. They had their waders on anyway and were heading out to fish."[18]

Other residents began to move to Freeport around 1920. First were New York City residents who built weekend retreats. Later, especially following World War II, were those seeking full-time permanent homes. A building boom occurred during the 1950s, and the full-time population began to swell in the old meadowlands, now referred to as South Freeport. With the new residents came a demand to reduce the constant flooding. In 1960 and 1961, the village responded with drainage work and road grade level raising in South Freeport. This original flood mitigation work was entirely paid for by the Village of Freeport.

In 1983, Freeport began to routinely elevate streets in South Freeport. Because of the cost, the time to complete the elevation of all streets at flood risk was estimated to be decades. To this point, the majority of the financing, between $1 and $2 million annually, came from the issuance of general obligation bonds. However, periodically, after 1983 Freeport has received financial assistance from both the state and federal Departments of Transportation. By the mid-1990s, many streets had been elevated, including Woodcleft Avenue, which is now a fishing and tourist attraction as well as the most significant commercial business district. The Village of Freeport and private citizens raised $10 million to redevelop the Nautical Mile, including installation of new bulkheads, replacement of overhead electric wires with underground wiring, and construction of new upscale restaurants.

In its Project Impact Baseline Report, completed in 2000 shortly after the start of Project Impact, Freeport noted that it was at risk from hurricane and tornado winds and tidal flooding. In its Project Impact Progress Report completed a year later, Freeport noted that just 1 percent of its building stock met the current building code standard for wind and that 4,000 of a total of 12,000 homes and an unspecified number of businesses were currently located in the regulatory floodway. The high flood risk was reflected in FEMA NFIP statistics; between 1978 and 2003, FEMA paid a total of 1,448 flood insurance claims totaling $10.1 million.

Freeport also noted in the two Project Impact reports that it had adopted a Flood Mitigation Plan in 1997 and that it had one of the most stringent building codes for the New York area, "above and beyond the New York State Building Code." For example, Freeport adopted a 100-mile-per-hour (mph) wind load as opposed to the 75-mph load specified in the New York State Building

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[17] Ibid., p. 61.

[18] "'Rising to the Challenge', Freeport, N.Y.," *American City & Country*, December 1998.

Code. Freeport entered the NFIP in 1976 and joined the Community Rating System (CRS) in 1992; it had a Class 8 rating in 2001.

5.2.1.1 FEMA Hazard Mitigation Grants Awarded to Freeport, New York

Freeport has received six FEMA hazard mitigation grants since 1997, all related to elevating roads or individual private residences above the 100-year floodplain (Table 5-1).

Table 5-1 HMGP and FMA grants awarded to Freeport, New York[19]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1196	4063	Grade and raise road improvement project	Infrastructure protective measures (roads and bridges)	5/24/99	1,144,902	858,677
1296	0010	Elevate residential structures above BFE [Base Flood Elevation]	Elevation of private structures – coastal	7/12/01	783,620	120,413
1335	0010	Elevate road	Infrastructure protective measures (roads and bridges)	1/2/02	1,523,000	1,142,250
--	FMA-PJ-02NY-1997001	Elevate residential structures	Elevation of private structures – coastal	9/16/97	441,240	330,930
--	FMA-PJ-02NY-1998001	Elevate residential structures	Elevation of private structures – coastal	7/27/98	741,173	555,880
--	FMA-PJ-02NY-1999006	Elevate residential structures	Elevation of private structures – coastal	10/16/99	216,360	162,270

One of the Hazard Mitigation Grant Program and the three Flood Mitigation Assistance grants were received by Freeport between 1997 and 2001. They totaled just over $1 million in federal funds and were used to elevate 23 individual private houses in South Freeport. All seven persons interviewed by telephone were familiar with and had some information on these grants. They reported that the major objectives were: "reducing property damage" (number of respondents = 3); "reducing residents' disruption and displacement" (number of respondents = 1); "reducing business disruption" (number of respondents = 1); "reducing insurance premiums" (number of respondents = 1); and "increasing property values" (number of respondents = 1). Interviewees said that these grants were successful. Participating homeowners, who had to contribute the full local match of 25 percent of the total cost (as much as $25,000 of a $100,000 elevation), benefited from "increased property values," "reduced insurance losses," and had "no

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[19] Data for this table comes from the NEMIS database.

further flood (insurance) claims" since the elevations occurred. The interviewees also believed that there were failures associated with the grants. One said "[when the] project ended, there were other homes we wanted done" but they could not be done. Another mentioned that some homeowners could not afford the 25 percent match and therefore could not participate.

In 1999 and 2002, Freeport received the two remaining HMGP grants totaling $2 million to elevate two segments of streets whose crests were below the level of the 100-year floodplain. The total amount provided by FEMA was approximately equal to what the community would spend on road elevations in a two-year period or less than 10 percent of the total spent so far on elevating roads.

Telephone respondents were familiar with one or both of the street elevation grants. Just as for the house elevation grants, they thought the major objectives of the street elevation grants included "reducing stress and trauma" (number of respondents = 1), "reducing property damage" (number of respondents = 1), "reducing residents' disruption and displacement" (number of respondents = 1), and "stimulated local economy" (number of respondents = 1). The interviewee who mentioned the latter objective elaborated, saying "[Freeport] is a now a major destination in Long Island. Private sector got involved, three or four new restaurants, miniature golf, tourist shops, electrical moved underground. . . ."

5.2.1.2   Project Impact Grant

Freeport received a Project Impact grant in 1998.[20] Freeport proposed 13 activities that it divided into two general categories, those concerned with "education" and those broadly concerned with "retrofitting" for flooding and hurricane wind. Table 5-2 lists the Project Impact activities initiated by Freeport, including their benefits, completion details, and final status.

As described in Table 5-2, all but one of the 13 activities was completed with some degree of success. The only failure was the project that sought volunteer homeowners to raise their heating units to prevent damage from floods. All the homeowners who were asked to participate withdrew.

Two telephone interviewees knew about Project Impact and saw its major objectives as "improving disaster mitigation capacity," "becoming a disaster resistant community," and "laying the ground work for emergency management coordination."   When asked about how the Project Impact activities fit into the overall community hazard mitigation program, telephone respondents gave the following comments:

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[20] See Appendix Q for a complete description of Freeport's Project Impact grant.

Table 5-2 Project Impact activities initiated by Freeport

Activity	Benefits	Completion Details and Final Status
Education		
Project Impact coordinator	Salary	N/A
Public awareness events	Increase the public's awareness of natural hazard mitigation measures, preparedness and recovery	Held three Project Impact Awareness Days and one public awareness event for Nassau County elected officials. Freeport planned to continue to use public forums and mailings for disaster awareness and preparedness.
Mobile fire safety house/ disaster resistant house	Increase public's awareness of fire safety, natural hazard mitigation measures, and preparedness	Completed project. Purchased through contract, the Fire Safety House, a mobile classroom used mainly by the Freeport School District, a community partner. It is part of an ongoing education program.
Seminars and demonstrations on retrofitting	Increase public's awareness of natural hazard mitigation measures	The Freeport building department conducted site visits to educate home and business owners on mitigation measures. Two community partners, Simpson Strong-Tie and Home Depot, conducted workshops. These are ongoing activities.
Adult education classes on natural hazard preparedness	Increase public's awareness of natural hazard preparedness measures	Freeport Emergency Management Office developed and offered an adult education class on disaster preparedness through the Freeport School District. It is an ongoing course.
Communication network and video conferencing	Distance learning and transmission of emergency information	Completed project. Maintenance and expansion of the system will be supported by the Village of Freeport, Freeport utilities, and the Freeport school district.
Early warning system – tidal gauge	Reduce loss of property, thus reducing NFIP claims	Completed project. Record keeping, data production, and maintenance jointly supported by Freeport and the USGS.
Retrofitting		
Tree removal	Reduce loss of property	Part of a long-term program to remove trees that pose a threat to power lines and buildings and replace them with smaller "power friendly trees." Approximately $100,000 is allocated in the village budget to the program each year.
Preliminary design for road elevation projects	Reduce the effects of flooding	Paid consultant to prepare designs for elevating 13,400 linear feet of roadway of which 1,500 feet were completed and 11,900 scheduled for later construction. Part of an ongoing project that dates back to 1983.
Elevation of heating units	Reduction in flood insurance claims	Originally, $60,000 was allocated, but all homeowners who were contacted to participate in the program withdrew. Nothing was accomplished.
Hurricane resistant windows and doors for village emergency operation center	Reduction in damages due to wind	Project completed. Windows and doors were installed.
Bulkhead program	Reduction in flood damage and business losses	Progress was made to develop program to replace existing bulkheads along Woodcleft Avenue and the approval of bonds for homeowners to take out loans to replace their bulkheads. The program began prior to Project Impact and has continued since with portions of the project being completed and the first loan made.
Roadway grade raise and drainage improvement project	Reduce the effects of flooding	Ongoing program dating back to 1983 to raise all streets in the floodplain 3 feet above the level of the 100-year flood.

> Project Impact was not about dollars, [it] was about partnerships, people with problems going along with government and projects getting done.

> It was a catalyst that pushed us into full gear, spurred us on; we got aggressive.

> Project Impact gave us a goal to set up projects. Community wanted projects. Businesses were willing to jump on board. It was good.

Since Project Impact funding ended, several completed projects have continued with community support. The early warning system/tidal gauge placed in the bay is still maintained jointly by the Village of Freeport and the U.S. Geological Survey. At least five educational programs to increase public awareness of hurricanes, flooding, and measures to mitigate potential damage have become either ongoing activities or regularly scheduled educational courses.

The bulkhead improvement program that would replace deteriorating wooden bulkheads with hard plastic ones that are not affected by wood worms – the main cause of bulkhead deterioration – and raise them to 3 feet above the level of the 100-year flood was originally planned in 1993 when the village council approved a new bulkhead code to protect homes along the canals from flooding. Project Impact ended before the community was able to act on this project. Subsequently, the community council developed a plan and approved the issuance of bonds to provide low-interest loans to citizens for the purchase of bulkheads. Citizens would pay back the loans through assessments on their utility bills. The first bulkhead improvement loan was approved in summer 2004.

Since Project Impact concluded in 2001, officials of the Village of Freeport who were in charge of its programs have become advocates of hazard mitigation throughout the state of New York, especially in Nassau and neighboring Suffolk Counties. They speak to other communities and promote mitigation whenever asked.

Telephone interviewees thought Freeport's success in meeting major objectives of all FEMA-funded activities, including Project Impact, were very high ─ ranging from 7 to 10 on a 10-point scale ─ and that the community's ability to accomplish these same objectives without FEMA funding was very low, ranging from 1 to 2.

Five of the seven telephone interviewees thought that Freeport had a natural hazard mitigation program that was "much better" than those of other communities. Six of the seven stated that the community has plans to expand its natural hazard mitigation activities. On a scale of 1 to 10, all seven thought the program was very appropriate (mean = 9.4; standard deviation = 1.1) and effective (mean = 9.6; standard deviation = 0.5) for Freeport's needs.

When asked to assess the community's overall natural hazard mitigation program, respondents gave the following answers:

> Aggressive program to help prevent damages by natural causes.

> Freeport started getting serious in 1992. Formed Emergency Management Team. Goes to conferences annually. Goes after mitigation. Gets involved a lot. Very aggressive in last 6-7 years especially.

> It's excellent. The Village fathers are proactive, have gone leaps and bounds to alleviate the problems in the Village.

> Very proactive in terms of flooding, wind, hurricanes, storms.

> Mayor and Board of Trustees comprise political body [that] controls mitigation. [The] goal is to be flood-free. We do education, are part of CRS [Community Rating System] and should be moving to 7 soon.

> We've taken the lead almost countrywide. There are a number of different mitigation efforts: we've raised most roads, there are ongoing projects – both private and commercial. The Nautical Mile just completed a $7 million project.

As noted above, both the street elevation and the bulkhead improvement activities began prior to the receipt of FEMA hazard mitigation grants. In addition, while FEMA has contributed to these activities, the funds received from FEMA were a fraction of the total amount spent. Using the definitions of synergistic activities discussed in Section 4.3.5, the elevating streets mitigation activities are considered collateral activities and the Nautical Mile redevelopment is a spill-over effect. The bulkhead improvement activities are considered a collateral activity.

5.2.1.3 Activity Chronology

An activity chronology was created for Freeport that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-1).

5.2.2 Hayward, California

The City of Hayward, California, is located on the east shore of the San Francisco Bay, 25 miles southeast of San Francisco, 14 miles south of Oakland, and 26 miles north of San Jose. It encompasses approximately 45 square miles and its population was 140,000 in 2000. The city was incorporated in 1876 and then included what is today the downtown business district that straddles the Hayward earthquake fault. The city remained relatively lightly populated until the 1960s.
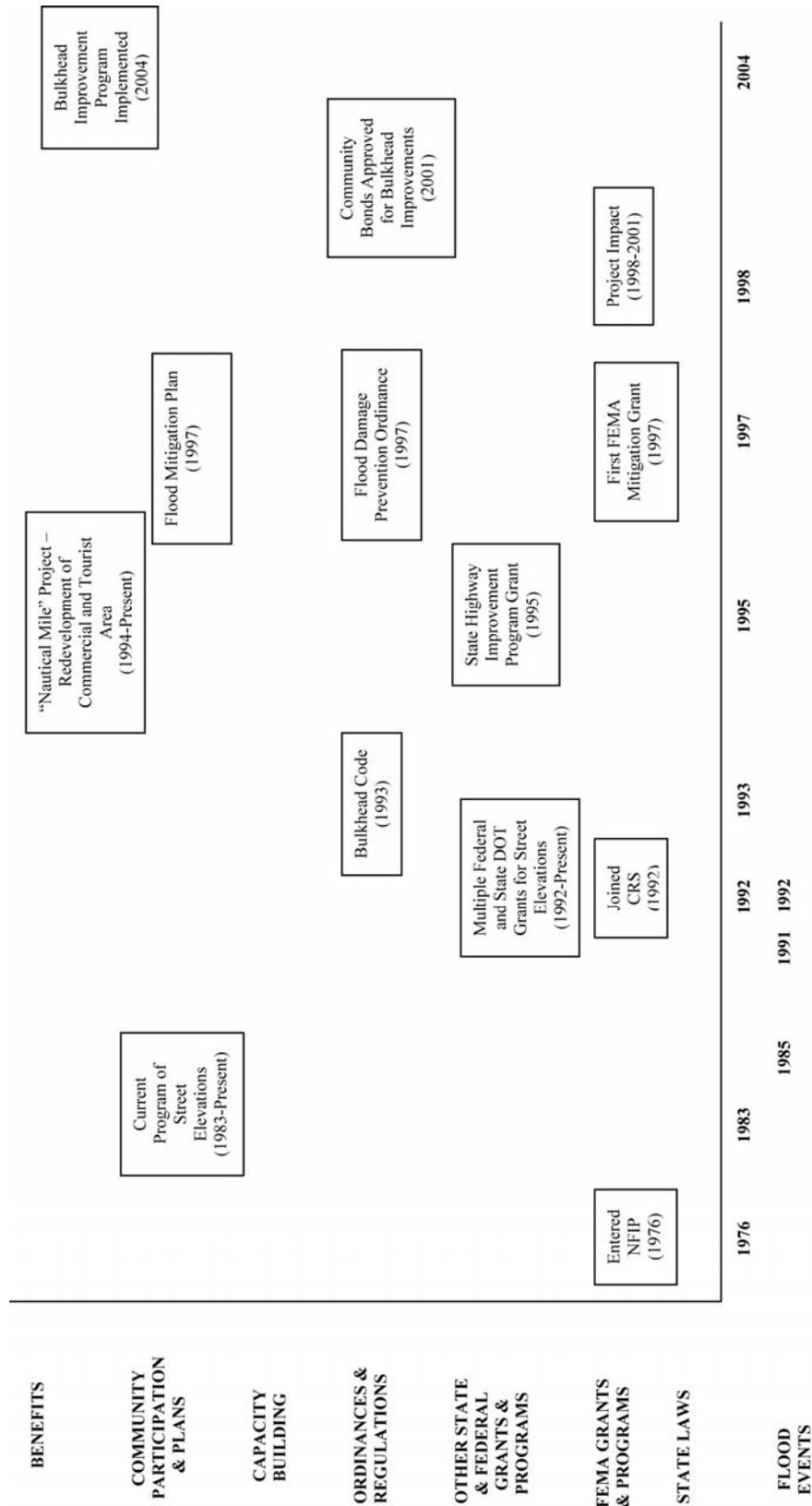
Figure 5-1 Activity chronology for Freeport, New York (unless otherwise indicated, activity dates above show start date).

Although the city is in "earthquake country," it has not suffered severe damage from any earthquake. Even in the 1989 Loma Prieta earthquake, which caused considerable damage in nearby communities like Oakland, Hayward had only light damage.[21]

Prior to 1986, when the state of California enacted the Unreinforced Masonry (URM) Building Law, Hayward did not have an earthquake hazard mitigation program.[22] The URM Building Law mandated that all communities identify all URM buildings that were potentially hazardous and then establish a mitigation program including at least the notification to the legal owners. The deadline for turning in the list of URM buildings was January 1, 1990.

When asked whether Hayward had a natural hazard mitigation program, five persons interviewed by telephone said yes, one person said no, and one person did not know. None of the five respondents thought they knew much about the program (mean = 3.4 on a scale of 1 to 10; standard deviation = 2.8). Those who commented thought the focus was on earthquake.

To meet the state requirements of the URM Building Law, the City of Hayward formed the Hazardous Building Mitigation Task Force to create an inventory of *all* seismically hazardous buildings in its jurisdiction. The Hazardous Building Mitigation Task Force included URMs built before 1944, all tilt-up buildings constructed prior to the 1973 building code adoption, and all high-occupancy (300 or more persons) reinforced concrete buildings built prior to 1976. Before the inventory was completed, the Loma Prieta earthquake struck northern California. In the next year, Hayward not only completed the inventory but also established hazard mitigation programs to retrofit the URMs and tilt-up buildings and secure HMGP grants to retrofit public buildings (see Table 5-3 for a list of HMGP grants). The initial count of seismically hazardous buildings as of October 16, 1990, was 282, of which 72 were URMs, 185 were tilt-ups, and 25 were high occupancy.[23]

5.2.2.1 Hazard Mitigation Grants Awarded to Hayward, California

In the year following the 1989 Loma Prieta earthquake, five important events occurred that led Hayward to adopt many mitigation activities. First, the Hazardous Building Mitigation Task Force was given the additional task of recommending mitigation activities the city should undertake. Second, the state Office of Emergency Services established priorities for funding under FEMA's Hazard Mitigation Grant Program.[24] The top eight priorities were:

1. Repair and retrofit of URMs;

2. Repair and retrofit of nonductile concrete structures, including pre-cast tilt up buildings;

3. Retrofit of privately owned buildings;

4. Retrofit of essential public facilities;

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[21] This community study focuses on the earthquake risk in Hayward. Hayward is also subject to flooding and entered the National Flood Insurance Program (NFIP) in 1981. However, it has never suffered a serious flood. According the FEMA NFIP statistics, from 1978 through 2003, FEMA paid just 11 flood insurance claims totaling less than $50,000.

[22] Hayward adopted seismic building codes that governed the construction of new buildings in accordance with California state regulations.

[23] City of Hayward Agenda Report, Agenda Item 15, October 16, 1990 (includes as an attachment a report on the Hazardous Building Mitigation Program submitted by the Hazardous Building Mitigation Task Force November 28, 1989).

[24] Letter from Paula Schulz to Elliott Mittler, December 16, 2003.

5. Mitigation of hazardous materials spills;

6. Hardening of communication systems;

7. Emergency public information; and

8. Alternate or mobile emergency operating systems.

Because the first three priorities generally apply to privately owned structures, none were feasible for consideration in HMGP grants. Hayward, in response to a call for HMGP proposals, submitted applications for the following eight projects:

1. "Seismic retrofit of the city center building,

2. Seismic retrofit of the police station,

3. Seismic retrofit of the main library,

4. Seismic retrofit of Fire Stations 2 through 6 and Corporation Yard buildings,[25]

5. Relocation of Fire Station 1,

6. Hazmat release prevention and response equipment,

7. Mobile communications center, and

8. Emergency public information."[26]

Four submittals were eventually approved (Table 5-3).

Table 5-3 FEMA Hazard mitigation grants awarded to Hayward, California[1]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
845	0014	Hazardous materials release prevention / response equipment	Other equipment purchase and installation	12/31/91	811,575	405,788
845	0015	Relocation of Fire Station 1	Structural retrofitting/rehabilitating public structures — seismic	5/3/94	3,186,000	1,593,000
845	0074	Seismic retrofit – Fire Stations 2, 3, 4, 5, 6, & Yard Building.	Structural Retrofitting/ rehabilitating public structures – seismic	4/9/92	980,000	490,000
845	0079	Emergency public information	Public awareness and education (brochures, workshops, videos, etc.)	4/9/92	20,800	10,400

[1] Data for this table comes from the NEMIS database.

The first grant led to the reconstruction of the Hayward Wastewater Treatment Plant (state priority 5). The next two grants permitted the retrofitting and rebuilding of fire stations (state

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[25] A yard is a location where vehicles and equipment are maintained.

[26] Letter from Harvey Edmark, City of Hayward Department of Public Works, to Christopher D. Adams, State Hazard Mitigation Officer, California Office of Emergency Services, October 26, 1990.

priority 4). And the last grant permitted the city to develop an emergency preparedness handbook for citizens (state priority 7).

Third, the state legislature enacted Senate Bill 1250, the Earthquake Safety and Public Building Rehabilitation Bond Act of 1990, which was then passed by the voters on June 5, 1990. The bill provided for the issuance of $300 million in general obligation bonds for reducing seismic hazards in public buildings, with $50 million obligated for local governments. The State Architect was responsible for determining which projects would be eligible and the procedures for submitting applications. Final rules were not worked out until March 1993, and submittals were due on October 15, 1993.[27]

After the submittals, the State Architect approved 114 projects, including seven for Hayward (Table 5-4).

Table 5-4 Projects approved for the city of Hayward funded under the State of California Earthquake Safety and Public Building Rehabilitation Bond Act of 1990

Project	Award ($)
Rebuild Fire Station 1	584,750
Hayward Air Terminal (HAT) Tower Generator	79,190
EOC and Corporation Yard Emergency Generators	533,250
Fairview Fire Generator Project (reinforce masonry walls)	21,375
City Center Structural Retrofit	500,000
Highland Reservoir Emergency Generators	567,000
Portable Emergency Generator for Emergency Water Well A	72,750

The first project listed in Table 5-4 was the same as the HMGP grant to relocate Fire Station 1. The funds from the state were used as part of the local match.

Fourth, in January 1989, the Hayward city council adopted the goal of retrofitting all vital city facilities including those that received HMGP awards, estimated at $15 million not including any state or federal grants.[28] Measure E, developed by the Hayward director of finance, asked for $15 million in general obligation bonds and was placed on the local April 10, 1990 ballot. It received about 57 percent of the vote, but failed to reach the required two-thirds needed for passage.[29]

The Hayward director of finance then was asked to find a funding alternative. Eventually, an ordinance establishing the Emergency Services Facilities Tax to generate the needed funds to repay the bonds was recommended. These funds would be collected as part of the normal

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[27] *Local Government State Grant: Earthquake Safety and Public Buildings Rehabilitation Bond Act of 1990*, Division of the State Architect, Sacramento, California, January 1994.

[28] At this time the local match on HMGP grants was 50 per cent.

[29] City of Hayward Agenda Report, Worksession Item #1, June 19, 1990 (includes a report Financing Alternatives for Earthquake Safety Retrofit Program submitted by the Director of Finance).

residential bill for water service and in the same manner as business taxes were collected. The ordinance was adopted by the city council on September 18, 1990.[30]

Fifth, the Hazardous Building Mitigation Task Force recommended to the city council that the owners of privately owned URMs and the tilt-up buildings identified as potentially hazardous be required to be retrofit. Ordinances for the retrofit of URMs and the tilt-ups were adopted by the city council on November 13, 1990. Both the URM and the tilt-ups were required to meet the seismic provisions of the 1973 Uniform Building Code. Owners of URMs were given approximately 5 years to retrofit, and owners of tilt-ups were given approximately 3 years to retrofit. According to building officials interviewed during the community site visit, there was little opposition. All the tilt-ups were retrofit and all but two of the URMs were retrofit.[31]

In the course of attempting to complete its retrofit program, the city made significant changes to three of its four HMGP projects. First, the reconstruction of the Hayward Wastewater Treatment Plant was originally intended to be a structural retrofit. Instead, a new plant was constructed using a technology that posed less of a hazardous materials threat. Second, Fire Station 1 was not retrofit. Instead, it was torn down and rebuilt. Third, after the emergency preparedness handbook was written, a translation from English into Farsi was printed but the original artist successfully sued the city for copyright infringement and the city had to destroy all the copies. One interviewee believed that a substitute publication was created, but no copy was located.

Four of the seven telephone interviewees had some knowledge of the HMGP projects and two said they were extremely involved in the design and implementation of the projects. In contrast, one respondent thought the reconstruction of the treatment plant and the seismic retrofit of fire stations and yard buildings was ongoing in 2004 when, in fact, all four grants were completed by the late 1990s. Major benefits of the four HMGP grants were reported to be: reducing death, injury and illness (number of respondents = 1); reducing environmental damage (number of respondents = 1); reducing stress and trauma (number of respondents = 1); improving emergency response capacity (number of respondents = 3); and public education about risks and risk reduction options (number of respondents = 1). An additional benefit of the emergency preparedness handbook, volunteered by respondents, was that it provided "a sense of community [that we] can make [the] community better, stronger." All respondents thought that the objectives had been attained and that the likelihood that these objectives would have been attained without FEMA funding was substantially lower.

After the Loma Prieta earthquake, the 11-story city hall building was abandoned. City officials moved to an existing building and planned to retrofit that building. Eventually, the cost was deemed prohibitive and a new city hall was constructed on base isolators.[32]
The City of Hayward has continued to develop proposals for the retrofit of its few remaining seismically hazardous public buildings. It is currently planning to either retrofit its main library or construct a new one. It is also retrofitting all its remaining water storage facilities.

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[30] City of Hayward Agenda Report, Worksession Item #26, June 9, 1992 (includes a Status Report on Seismic Retrofit Program Funding).

[31] The city is still pursuing the owners of the two remaining URMs to retrofit and expects to shortly get compliance. Both were delayed because of problems identifying legal owners.

[32] The total cost of the City Hall was borne by the city.

Determining what effect FEMA's HMGP grants had on the city was a difficult task. Before the Loma Prieta earthquake, which led to the HMGP grants, the Hayward Hazardous Building Mitigation Task Force was already inventorying its URM buildings as required by state law but also included pre-1973 tilt-up and pre-1976 high-occupancy reinforced concrete buildings in the inventory of hazardous buildings. Interviewees had mixed feelings about the impact of HMGP grants, especially on the enactment of the mandatory URM and tilt-up retrofit ordinances. Some said that seeing the damage in the Santa Cruz area following the earthquake convinced them that something should be done immediately. Others thought that the city council's enactment of a funding mechanism that would include paying the city share of the HMGP grants had an effect on the timing of the two ordinances. Others thought that FEMA actions had no impact.

It was ultimately decided that the enactment of the two retrofit ordinances would be considered to be "spin-off" activities. Because opinions were varied, the decision was based on the fact that Hayward had no prior history of mitigation activities. If the earthquake and subsequent HMGP grant opportunity had not occurred, it was not likely that the city would have done anything beyond creating the inventory of hazardous buildings. Up to 1990, only a handful of California communities had enacted either voluntary or mandatory URM retrofit programs and none had enacted a tilt-up retrofit program. In addition, the city council committed itself to mitigation by first adopting the funding ordinance to pay Hazard Mitigation Grant Program local shares in September 1990 and then, in October 1990, adopting the two retrofit ordinances. It seemed that the city council wished to commit the city to the retrofit of public buildings before asking private owners to retrofit their buildings.

5.2.2.2 Project Impact

Hayward did not participate in Project Impact.

5.2.2.3 Activity Chronology

An activity chronology was created for Hayward that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-2).
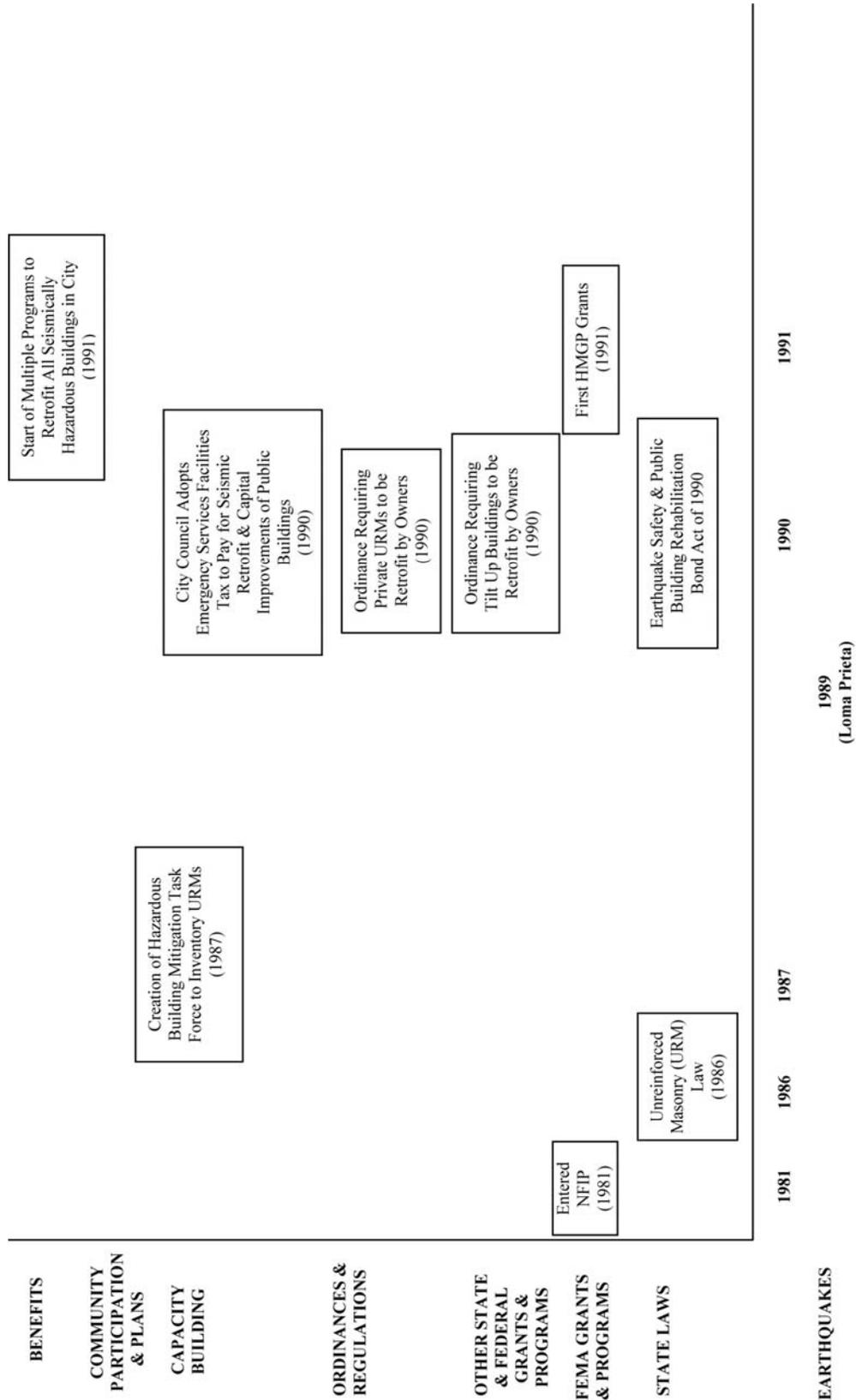
Figure 5-2 Activity chronology – Hayward, California (unless otherwise indicated, activity dates above show start date).

5.2.3   Horry County, South Carolina

Horry County is located on the Atlantic Coast and is bordered on the north by the state of North Carolina. The county is approximately 100 miles north of Charleston, South Carolina. It encompasses 1,134 square miles and had a population of over 196,000 year-round residents in 2000. Approximately 60,000 people live in its four largest incorporated cities, Conway, Myrtle Beach, North Myrtle Beach, and Socastee.

The county is relatively flat and is filled with wetlands and rivers. It also has a lengthy beachfront. It was incorporated in 1801 and remained a small, secluded community until the railroad arrived in 1887. Developers then turned the beach into a resort location. A construction boom in the 1970s and 1980s doubled the population (66,992 in 1970 to 144,053 in 1990). Today the Census reports that the area is the thirteenth fastest growing region in the country. According to the Myrtle Beach Economic Development Corporation, more than 13 million tourists visit the beach areas, called the Grand Strand, each year, mostly during the summer months at the height of the hurricane season.

Horry County was the only community in this study that is at risk from floods, hurricanes, and earthquakes. The county has been flooded several times in the past century; because of the flat and swampy terrain, floods are typically slow rising, slow moving, and long lasting. The county has also been the victim of multiple hurricanes, including several since Hurricane Hugo in 1989. Even though the county is located in an earthquake zone, it has not been affected by one since the Charleston earthquake of 1885.

When evaluating the risks from natural hazards, the six telephone interviewees thought that Horry County was a risk from flood (mean = 8.67 on a 10-point scale; standard deviation = 1.0) and wind (mean = 8.67; standard deviation = 1.4) but not earthquake (mean = 3; standard deviation = 2.5).

Prior to Hurricane Hugo, Horry County and the largest incorporated cities (Conway, Myrtle Beach, and North Myrtle Beach) joined the National Flood Insurance Program. In 1987, the Horry County Council adopted Ordinance No. 8-87 that authorized the appointment of a flood hazard reduction officer to review all development permits to ensure that all new structures met NFIP compliant regulations including that the first floor be elevated above the 100-year flood level. The flood hazard reduction officer was placed in the Engineering Department where evaluations of new construction are made. In 2000, the county adopted a Stormwater Management and Sediment Control Ordinance to control changes in rain runoff caused by urban development. The ordinance requires contractors to provide for the construction and maintenance of storm drains, ditches, and ponds to reduce flooding, erosion, and pollution problems.

When asked about the county's hazard mitigation program, the mean knowledge score of the telephone interviewees was 4.8 (standard deviation = 4.0) on a 10-point scale. In spite of the wide range of knowledge, five of the six respondents thought Horry County's program was "much better" (5 on a scale from 1 to 5) than those in other communities. When asked for their overall assessment of the program, respondents provided the following statements:

County does a good job educating the public to prepare for disasters. Don't know much about it. Not a lot of knowledge about what the county is doing. I know they have raised houses down by the coast.

Don't know anything.

I think we have an excellent program – managed well through the emergency coordinator.

Not familiar with it.

Pretty good. Further along than most. Top in the state – have had several presidentially declared disasters which opened [us] up [to] HMGP grants. Spent lots of dollars on mitigation. HMGP used to implement mitigation grant projects - $5 or $6 million.

We do quite a bit to reduce the damages. Over the last seven or eight years a number of grants, acquisitions, elevations, beach erosion, strengthening of public buildings.

5.2.3.1 Hazard Mitigation Grants Awarded to Horry County, South Carolina

Horry County received its first FEMA HMGP grant to develop a beach renourishment plan after Hurricane Hugo in 1989 (Table 5-5). Only one of the six telephone interviewees was familiar with the grant. That person said its major objective was "enhancing a critical public resource."

According to interviewees, a Local Beach Comprehensive Beach Management Plan was written, implemented once, and then apparently forgotten.[33] Five of the six telephone interviewees remembered this project but thought that it had been funded by the county, not by FEMA.

Following Hurricane Floyd in September 1999, Horry County received several grants to acquire private houses substantially damaged by floods, to elevate private houses substantially damaged by floods, and to retrofit public buildings for wind and earthquake. The majority of the funds received were used to purchase private houses, many with repetitive NFIP losses. Three telephone interviewees were familiar with the projects and thought the major objective was to "reduce property damage."

Throughout the country, communities typically either sell the acquired houses so they can be relocated out of the floodplain or tear them down. Horry County, however, decided to join a Clemson University civil engineering professor in a project that would involve destruction of 13 houses systematically to test their ability to withstand forces equivalent to strong winds (Reinhold, 2002). The project was funded by a grant from the South Carolina Department of Insurance and an additional contribution from the Institute of Business and Home Safety. Also taking part in the project were the Horry-Georgetown Homebuilders Association and local building inspectors. Three of the telephone interviewees knew of the project and identified it as a "spin-off" of a HMGP grant. The results of the study will be used to make recommendations for improving wind resistance in private houses and to support the development of proposed changes to the nation's model building codes and standards.

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[33] No copy of the plan could be found at the FEMA regional office, at the state emergency management office, or at the county. No one was located who could remember when it was last used or its content.

**Table 5-5 FEMA hazard mitigation grants awarded to
Horry County, South Carolina[1]**

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
843	0019	Local beach management plan	Mitigation plan - local multihazard mitigation plan	4/14/95	30,000	15,000
1243	0006	Horry County public buildings window and portal protection	Retrofitting public structures – wind	5/3/00	72,585	54,439
1243	0007	Horry County acquisition of two properties	Acquisition of private real property (structures and land) – riverine	2/14/01	383,567	287,676
1299	0014	Horry County elevation project	Elevation of private structures — riverine	Not available	Not available	97,502
1299	0021	Horry County property acquisition	Acquisition of private real property (structures and land) – riverine	11/12/03	794,179	595,634
1299	0032	Horry County critical facility retrofit	Structural retrofitting / rehabilitating public structures – seismic, and retrofitting public structures — wind	1/19/02	415,600	311,700
4299	003	Horry County acquisition (Supplemental to 1299)	Acquisition of private real property (structures and land) – riverine	7/24/00	2,780,326	2,085,245
4299	005	Horry County acquisition (Supplemental to 1299)	Acquisition of private real property (structures and land) – riverine	Not available	1,374,545	1,030,909

[1]Data for this table came from the NEMIS database.

Horry County was eager to participate in the study because expectations are that thousands of houses will be constructed in the county in the near future and, while all will be constructed

above the level of the 100-year flood, they still will be subject to hurricane wind.[34] It is considered to be a direct spin-off of the HMGP acquisition grants.

After the buyouts, Horry County made arrangements with neighbors or homeowners associations to maintain the cleared properties and eliminate long-term maintenance costs. Their primary use is open space. In a few cases, however, the county uses the cleared locations adjacent to rivers with boat ramps as emergency access points to the river system and for annual exercises by the fire department or other emergency services department. The goals are to limit drowning, improve the response time in emergencies, and provide staging areas for floods or sites for disaster field offices.

In addition to the HMGP grants to purchase houses, Horry County received one grant to elevate four private houses. Five telephone interviewees knew of the grant but were not very familiar with it (mean = 2.6; standard deviation = 3.6). As a rule, owners of substantially damaged houses who had riverfront property were reluctant to sell but agreed to elevate their houses instead.

Horry County also received a HMGP grant to retrofit four county buildings for both wind and earthquake. Again, five telephone interviewees knew of the grant but were not very familiar with it (mean = 2.6; standard deviation = 3.6). The majority of the funds were spent on providing wind shutters for the buildings. A review of the engineering descriptions of the projects indicated that there was no earthquake retrofit planned or completed.

5.2.3.2 Project Impact

In 2001, Horry County received a Project Impact grant for $150,000. FEMA made the announcement of the award just after the agency had announced that Project Impact was being discontinued. The coincidental announcements had a depressing affect on the community. One telephone interviewee said "This administration is not behind Project Impact. FEMA [is] not promoting [it, which] makes it hard to get [community] buy-in. [It's] not even part of the FEMA website. Focus is on terrorism. [We] still need natural disaster mitigation."

The Project Impact director tried to complete the items in the memorandum of agreement the community signed with FEMA, but there was a pall over the project that prevented the county from attracting long-term partners. The county partially or fully completed nine of eleven planned activities including its four top projects: enhancing the weather detection system by placing four new units on the roofs of fire stations; developing a critical facilities/hazard risk assessment GIS capability; placing road reflectors to identify the location of fire hydrants; and creating public service announcements for television that promoted the Resident and Tourist Hazard Awareness Program. The first three activities are still being maintained by the county. In addition to these projects, there was several small education projects aimed at school children. Horry County was unable to complete several projects including the Resident and Tourist Hurricane Awareness Program because the person intended to produce several public service announcements to be broadcast on local television stations went on maternity leave. (See Appendix Q for a detailed examination of Project Impact.)

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[34] Contractors of expensive subdivisions interviewed in the field said they had already incorporated some of the results into their construction practices.

At the time of the field site visit, Horry County had not completed all its Project Impact projects and had not submitted a final report, and it appeared that many unfinished projects would not be completed. The Project Impact director mentioned that she was unable to spend all the allocated funds and had initiated action to return the unspent funds to FEMA.

Two telephone interviewees commented on what Project Impact did for the community. The first said that "it brought the community together – homeowners, businesses to plan more effectively – look at areas of vulnerability privately and corporately."   The second said that Project Impact "supplemented the [hazard mitigation] program. Added more community outreach; everyone benefits."

5.2.3.3 Activity Chronology

An activity chronology was created for Horry County that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-3).

5.2.4 Jamestown, North Dakota

Jamestown is a small rural city with a stable population of 15,500. It is located in east central North Dakota, midway between Bismarck and Fargo, at the confluence of the James and Pipestem Rivers. Jamestown has had a history of flooding, mostly caused by spring runoff from melting snow in upstream mountains. Because of recent high water tables, heavy local rain storms can overwhelm the 100-year old sanitary and storm water sewer systems and cause basement flooding. Jamestown was included in 11 Presidential disaster declarations related to flooding between 1966 and 1999.

The Bureau of Reclamation constructed the Jamestown Dam and reservoir in 1954 on the James River above the city to lessen the probability of floods. Flooding in the southern half of the city was still possible, however, because the Pipestem River, a tributary of the James, ran wild. In 1973, the U.S. Army Corps of Engineers completed the Pipestem Dam and lake to control river flows.

Since 1973, flows of the James and Pipestem rivers have been regulated by the U.S. Army Corps of Engineers. There is still a small probability that the two dams will not be adequate to prevent overbank flooding beyond the 100-year level. Three floods in the mid-1990s demonstrated that additional physical projects were needed to protect the city dry from a rising river. However, after becoming a Project Impact community in FY 2000, when asked in the Project Impact Baseline Report what natural hazards threaten the community, Jamestown officials listed "flash flooding following heavy rains" and did not mention overbank floods of the James River.
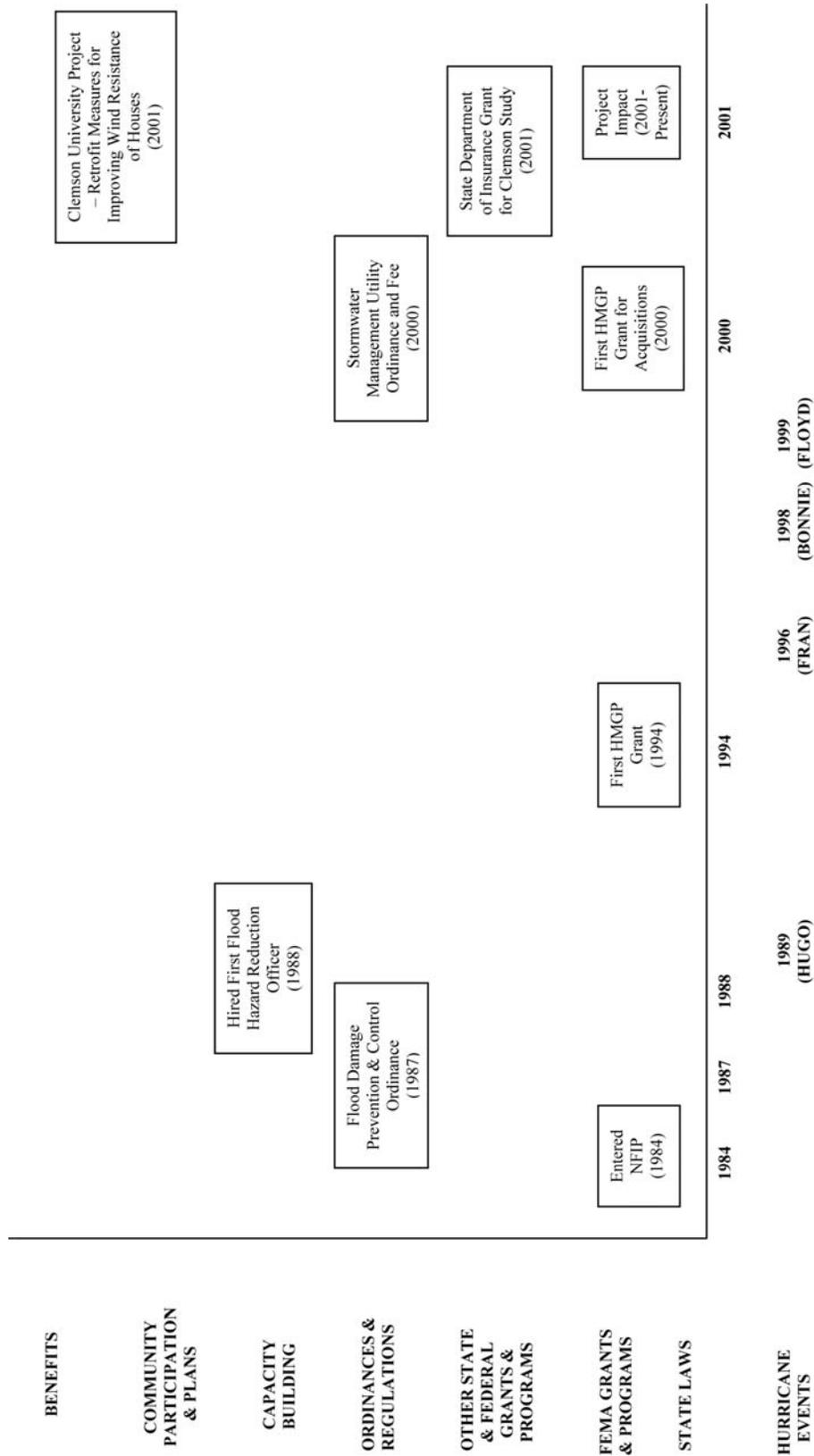
Figure 5-3 Activity chronology – Horry County, South Carolina (unless otherwise indicated, activity dates above show start date).

There are very few structures vulnerable to flooding. According to the Project Impact Baseline Report filled out by community officials after Jamestown became a Project Impact Community, only about 60 of the city's 5,000 houses and 600 businesses were located in the regulatory floodplain. Current FEMA statistics show that in the 26 years from 1978 through 2003 there have been only 26 paid NFIP claims totaling $64,000. The Baseline Report also listed high winds and tornadoes as threats to the community. One telephone interviewee summed up the situation, saying "[We] don't have tornado shelters – need a few. From a flooding stand point, [we are] probably the safest place in the state. [We] have an adequate [hazard mitigation] plan. Need better, but costs money."[35]

Jamestown joined the National Flood Insurance Program in 1972. In accordance with the program's regulations, Jamestown adopted ordinances regulating building in the floodplain. According to information provided in the Project Impact Baseline Report, these are the only city ordinances that include mitigation provisions.

When asked in the Baseline Report to identify public awareness campaigns or training classes currently being offered in the community, Jamestown officials listed four:

1. National Weather Service Weather Spotters Class for attendees to learn how to identify types of summer weather events;

2. An Emergency Services Day with booths set up at a local mall addressing floods, tornadoes, and school violence;

3. A school evacuation plan with evacuation and safety drills in case of fires or tornadoes; and

4. A public health fair with booths at a local mall demonstrating CPR and emergency response.

5.2.4.1 Hazard Mitigation Grants Awarded to Jamestown, North Dakota

Jamestown has received two HMGP grants (Table 5-6).

Table 5-6   FEMA hazard mitigation grants awarded to Jamestown, North Dakota[1]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1001	0016	Modification of lift station	Other equipment purchased and installed	4/4/95	45,002	33,750
1032	0001	Oxbow Dike flood control project	Flood control - berm, levee, or dike	7/15/97	517,660	376,701

[1] Data for this table comes from the NEMIS database.

The first was for the improvement of a lift station to prevent sewage backup problems, including the installation of wet well pumps to assure continuity of function. The second was for the construction of two box culverts and gate controls that would prevent flooding of private houses

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[35] Jamestown does not write its own mitigation plan. It is part of the county plan written by the Stutsman County Office of Emergency Management.

in a large oxbow area of the James River. During the 1997 flood, Jamestown also received a grant from the U.S. Army Corps of Engineers to install temporary dikes at different locations around the city as an emergency flood fighting measure. At the urging of the U.S. Army Corps of Engineers, the city also removed a bridge over the James River that had been responsible for holding debris and causing backup flooding when the river rose. Since the completion of the two FEMA projects, there have been no subsequent major floods to test the capacity of the two structures.

Eleven persons interviewed by telephone knew something about the improvement of the lift station. They felt that the existence of FEMA funds substantially increased the community's ability to attain objectives such as reducing property damage, reducing infrastructure damage, reducing residents' disruption and displacement, and reducing environmental damage over its ability without FEMA funds.[36]

Ten of the 11 respondents knew about the FEMA grant to install dikes at the Oxbow, although most had little involvement in the design. They had a similar opinion of the grant as that for the lift station. Respondents believed that the availability of FEMA funds increased its ability to accomplish objectives such as reducing death, injury, and illnesses, reducing property damage, and reducing residents' disruption and displacement over its ability without FEMA funds.[37]

5.2.4.2 Project Impact

Jamestown was awarded a Project Impact grant for $300,000 in December 1999.[38] The city and its Project Impact partners ultimately completed 10 of 13 projects proposed including:

1. A city-wide storm water runoff study;

2. Preparing Jamestown to qualify for and receive a "Storm Ready" designation from the National Weather Service;

3. GIS project implementation including installing and utilizing digital flood maps on the GIS system;

4. Establishing and implementing a 24 hour "skywarn system" by retrofitting a trailer to become a 24 hour emergency communication center;

5. Providing generators and other equipment including Red Cross emergency supplies to make the Civic Center a post disaster community shelter;

6. Improving the community early warning system by installing five new outdoor sirens and updating two existing ones (old sirens were recycled to smaller towns in the county);

7. Providing hazardous materials training to firemen and equipping a haz-mat trailer;

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[36] On a 10-point scale ranging from a low of 1 to a high of 10, respondents had a mean score of 9.2 (Standard Deviation = 1.3) when asked if the existence of FEMA funds substantially increased the community's ability to attain these objectives over its ability without FEMA funds (mean = 2.6, standard deviation = 1.5).

[37] Respondents had a mean score of 9.0 (standard deviation = 1.5) when asked if the existence of FEMA funds substantially increased the community's ability to attain these objectives over the its ability without FEMA funds (mean = 2.0, standard deviation = 1.2).

[38] Much of the information on Project Impact comes from the community's Project Impact Final Report that was issued on a compact disk in 2004. See Appendix Q for a complete description of Jamestown's Project Impact grant.

8. Conducting public awareness and education programs including purchase of computer equipment for disaster presentations and other safety classes, "Master's of Disasters" for elementary schools, purchase of weather radios for public buildings and all public schools, and purchases supplies for Red Cross emergency shelter;

9. Developing a model home demonstration project with students from the James Valley Vocational Center to show citizens how to protect their homes from wind and flood; and

10. Establishing a fire and police training facility for the region.

Not completed were projects to:

1. Implement the storm water runoff study,

2. Install storm sewer flood gate controls, and

3. Join the CRS and lower CRS rating from a 10 to 9.

Although the community categorized the first of the three projects listed above as not completed, it was actually integrated into in the first completed project and dropped as an independent project. Therefore, the community actually completed ten of twelve projects.

Project Impact was completed December 31, 2002. Since it ended, the community has maintained all the completed projects and begun either follow-on or additional projects. The local schools have instituted two follow-on projects to make schools safer and a new high school has been designed using a storm water runoff analysis based on the completed citywide storm water runoff study by Project Impact.

Ten telephone interviewees knew about Project Impact. Most were familiar with some aspects such as how much the community received from FEMA, how much the community match was, and that it provided the community with resources to meet such objectives as "improving emergency response capacity," "reducing death, injury, and illnesses," "improving disaster mitigation capacity," and "public education about risks and risk reduction options." As a group, they were more familiar with Project Impact than they were with the HMGP grants.

On the whole, Jamestown respondents did not think that they were as successful meeting stated objectives for Project Impact as they had been for the modification of the lift station and the Oxbow Dike Flood Control Project (mean = 8.8; standard deviation = 1.6); however, they felt that without Project Impact there would have been much less possibility of attaining the objectives outlined and the activities completed (mean = 1.8, standard deviation = 0.8).

According to respondents, partners were heavily involved in Project Impact activities. Partnerships formed for a variety of reasons including the Internet (number of respondents = 1), personal friendship (number of respondents = 1), community betterment (number of respondents = 2), company policy and good citizenship (number of respondents = 1), properties at risk (number of respondents = 1); and most cogently because it was required (number of respondents = 4)! Respondents pointed out that both the announcement and the city required that partners be involved if Project Impact monies were to be obtained, although one respondent stated that "partnerships already [were] formed, [we] didn't form [them] for Project Impact."

5.2.4.3 Activity Chronology

An activity chronology was created for Jamestown that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-4).

5.2.5 Jefferson County, Alabama

Jefferson County is located in north central Alabama on the southern extension of the Appalachians and is in the center of the iron, coal and limestone belt of the South. Approximately 150 miles west of Atlanta, Georgia, it is about 1,132 square miles in area and is the most densely populated county in Alabama with 662,000 people counted in the 2000 census. There are 35 political jurisdictions (incorporated cities or towns) in the county, the largest being Birmingham with a population of 242,000. The county was established in 1819 by the Alabama legislature.

A five-member commission with legislative and executive duties governs the county. By commission vote they divide executive responsibilities for the county departments such that each commissioner is the executive head of the agencies that fall under one of the five following categories: roads and transportation and community development, environmental services, health and human services, technology and land development, and finance and general services. Emergency management, planning, and land use fall under technology and land development.

Because of its geographical location in the foothills of the Appalachians, Jefferson County is susceptible to flash flooding and tornadoes. However, until being devastated by an F-5[39] tornado on April 8, 1998, the county government had not been very active in hazard mitigation.[40] On the other hand, in response to recurring floods on Village Creek, the City of Birmingham had independently participated in one of the largest buyouts of private houses in the United States (Mittler, 1997).[41]

When asked to assess the current hazard mitigation plan (that was funded through both Project Impact and two HMGP grants described below), nine of the ten persons interviewed by telephone said they knew something about the program; the mean was 6.67 on a scale of 1 to 10 where 10 indicates knowing a lot and the standard deviation was 2.18). Overall, the respondents believed that the plan was appropriate to the community needs (mean =

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[39] The F-5 notation refers to an "incredible tornado" on the Fujita scale, which rates the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure. It is associated with maximum wind speeds ranging from 261 to 318 miles per hour.

[40] A document entitled "Mitigation Projects and Studies" written by the Jefferson County Emergency Management Agency in 1999 indicates that joining the National Flood Insurance Program in 1982 and purchasing 21 outdoor warning sirens placed in various locations in the county were the only mitigation activities undertaken by the county until 1999. One of ten telephone interviewees believed the county had a hazard mitigation program that dated back to 1951, but the others either did not know when it started or considered it recent.

[41] A study conducted by the U.S. Army Corps of Engineers on the Village Creek floodplain in Birmingham led to the purchase of 642 structures.

New High School
Design Includes
Storm Water Runoff
Analysis
(2003)

Storm Water
Runoff Study
(Project Impact)
(2002)

2003

Project Impact
(1999-2002)

1999

USACE Grant –
Flood Fighting
(1997)

1997   1997

First HMGP
Grant
(1995)

1995   1995

1993

USACE Pipestem
Dam & Lake Open
(1973)

Entered
NFIP
(1972)

1973

Bureau of Reclamation
Jamestown Dam &
Reservoir Constructed
(1954)

1954

BENEFITS

COMMUNITY
PARTICIPATION
& PLANS

CAPACITY
BUILDING

ORDINANCES &
REGULATIONS

OTHER STATE
& FEDERAL
GRANTS &
PROGRAMS

FEMA GRANTS
& PROGRAMS

STATE LAWS

FLOOD
EVENTS

Figure 5-4 Activity chronology – Jamestown, North Dakota (unless otherwise indicated, activity dates above show start date).

8.22 and standard deviation = 2.1). Several respondents provided explanatory comments including:

> Community is being proactive – trying to take on activity of protecting its citizens. They are on their way. It's good. Haven't ended the journey, but they are on the road.
>
> Relatively good job. [The] Flood program has been [the] main focus.
>
> We have a progressive program for flood, tornado, and winter storms.
>
> I think it's good. It has become more updated in recent years. Just completed all hazards plan.

When asked to compare Jefferson County's program to those of other communities on a scale of 1 to 5 where 1 is much worse and 5 is much better, the mean score was 4.33 (standard deviation = 0.87).

The 1998 tornado killed 32 and injured over 200 residents of the county, many of them low income. In addition, the tornado destroyed 343 homes and damaged several hundred more homes and businesses. The county received several U.S. Department of Housing and Urban Development (HUD) grants to assist in recovery and provide low income residents with new or improved housing to replace that which was either destroyed or damaged in the tornado. At the time of the tornado, FEMA was just starting to promote the use of safe rooms and provided the state of Alabama an HMGP award to partially fund the construction of safe rooms in private houses in communities subject to tornadoes throughout the state.[42] The Jefferson County Emergency Management Agency coordinated the construction of 100 safe rooms in the county.

5.2.5.1 Project Impact

Jefferson County was awarded a two-year Project Impact[43] grant for $150,000 in April 1999.[44] Four activities were undertaken including:

1. The development of the 2001 Jefferson County Local Mitigation Strategy,

2. The creation of the "Web EOC" (an information systems upgrade of the county emergency operations center),

3. The initiation of the annual "Community Awareness Day" (a public education and outreach event held annually on the park between the Birmingham City Hall and the Jefferson County administrative complex), and

4. An upgrade of the Early Warning System (sirens).

The first three projects were completed on schedule. No Project Impact funds were used for the fourth project. During Project Impact funds for the upgrading were raised from other sources, and after Project Impact ended, upgrading began.[45]

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[42] Unlike other HMGP grants for local activities, FEMA grants for safe rooms were awarded directly to states rather than communities. Local governments coordinated the program in their jurisdictions, and the state reimbursed the participating homeowners for partial payment after inspections were completed that verified the safe rooms met the FEMA construction guidelines. This practice began earlier in 1999 in Oklahoma and Kansas.

[43] Jefferson County was the only community in this study that received a Project Impact grant before it was awarded either a HMGP or FMA grant. For clarity, the grants are discussed chronologically.

[44] Jefferson County later applied for and was granted a one-year extension, so the duration of Project Impact was three years.

All of the activities continued after Project Impact ended. The Local Mitigation Strategy became the foundation for the creation of the 2003 Natural Hazards Mitigation Plan. The EOC has been further upgraded with a new server, new software, and 40 laptops. Community Awareness Day occurred during the one year after the end of Project Impact but not thereafter. The U.S. Department of Justice awarded the county two grants in 2001 and 2003 to replace 30 old sirens, upgrade the remaining existing 127 sirens, and install between 80 and 90 new units. Finally, the Jefferson County Emergency Management Agency maintains its original Project Impact website as www.impactalabama.com.

5.2.5.2 Hazard Mitigation Grants Awarded to Jefferson County, Alabama

Only a few months after Jefferson County received its Project Impact grant, it was subject to severe flooding in June 1999 on Upper Shades Crest Creek, the first of what county officials believed were three 100-year floods in four years. Shortly after the flood, Jefferson County received the first HMGP grant directly awarded to it as a subgrantee (Table 5-7).

Between 1999 and 2001, Jefferson County received three HMGP and three Flood Mitigation Assistance grants to purchase severely damaged private houses in the floodplain, two HMGP grants to complete the Upper Shades Creek Flood Hazard Mitigation Plan, and one HMGP grant to create an Automated Hazard Mitigation Information System with GIS coverage for all hazards.

Most telephone interviewees were not familiar with or involved with the HMGP grants but thought that they met their objectives, normally giving scores of either 9 or 10 on 10-point scales. The exception was the Automated Hazard Mitigation Information System where four said they were involved in priority setting, carrying out activities, providing resources, and grant administration and management. Their reactions were mixed. When asked how they would rate the community's success in meeting the major objective of the Automated Hazard Mitigation Information System, some rated it low and others rated it high. Those who rated it low did not think it would work. However, one said "In practical terms, don't know if [the] system has been used." In response to a different question, one respondent said "System has capabilities to warn and didn't – example from last May's flood." Another respondent was worried that after the information arrived at the Emergency Operation Center there were no established procedures to handle the information. And another said there was "a major lack of foresight in terms of funding the maintenance. Some had been corrected in-house [e.g., for for clearing leaves from rain gauges], but [it] hasn't been corrected for major things [e.g., if lightening strikes disabling the rain gauges]."

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[45] When telephone interviewees were asked about Project Impact, only three of the ten were able to describe any Project Impact activities. Any comments they gave on mitigation projects in Jefferson county concerned HMGP grants and will be found below in a discussion of these grants.

Table 5-7 FEMA hazard mitigation grants awarded to Jefferson County, Alabama[1]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1208	0007	Automated Hazard Mitigation Information System	Other equipment purchase and installation	5/17/99	758,700	569,025
1208	0025	Jefferson County buyout	Acquisition of private real property (structures and land) – riverine	3/13/01	343,343	257,507
1214	0010	Jefferson County hazard mitigation plan	Mitigation plan - local multihazard mitigation plan	6/22/99	414,617	310,963
1214	0023	Jefferson County Five Mile Creek buyout continuation	Acquisition of public real property (structures and land) — riverine	3/20/01	337,334	253,008
1250	0007	Jefferson County hazard mitigation plan	Mitigation plan - local multihazard mitigation plan	6/29/99	77,383	58,037
1250	0020	Jefferson County buyout	Acquisition of private real property (structures and land) – riverine	9/25/00	1,913,602	1,435,202
--	FMA-PJ-04AL-1999001	Jefferson County, Alabama project	Acquisition of private real property (structures and land) – riverine	11/21/00	75,918	56,939
--	FMA-PJ-04AL-1999002	Jefferson County, Alabama project	Acquisition of private real property (structures and land) – riverine	11/21/00	212,015	159,011
--	FMA-PJ-04AL-1999003	Jefferson County, Alabama project	Acquisition of private real property (structures and land) – riverine	11/21/00	214,524	160,893

[1]Data for this table comes from the NEMIS database.

The county council became proactive on hazard mitigation during the aftermath of the 1998 tornado and the 1999 flood. The councilperson in charge of technology and land development was the key person responsible. She was the driving force behind the passage of a 2003 ordinance that allocates $2 million annually for the purchase and removal of private houses

throughout the county subject to severe flooding.[46] She also promoted the Community
Development Agency's initiative to provide safe rooms in the new Edgewater Oaks subdivision
that will ultimately contain 80 residences constructed for low income families.[47] HUD provided
the majority of the funds. Both of these activities were inspired by the HMGP grants and/or
Project Impact. Before the HMGP and Project Impact grants, the county was subject to recurrent
floods and severe tornadoes, but had not initiated hazard mitigation programs to address the
risks. Only after the county had participated in the FEMA-funded projects did the county take
any initiative. Also as described in more detail in Appendix Q, both the Project Impact
coordinator for the county and FEMA Region 4 representatives attributed the initiation of the
safe room program to Project Impact. Because of the timing between the FEMA projects and the
subsequent county programs and beliefs expressed by the local officials, the initiatives taken by
the councilperson are both spin-offs of the FEMA grants and/or Project Impact.

5.2.5.3 Activity Chronology

An activity chronology was created for Jefferson County that illustrates the relationship between
FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged
by the FEMA grants (Figure 5-5).

5.2.6 Multnomah County, Oregon

Multnomah County is located in northwest Oregon along the Columbia River. It is bordered on
the north by the state of Washington. The county is one of three contiguous Oregon counties,
including Hood River and Wasco that are part of the Columbia River Gorge National Scenic
Area. All lands that can be seen from the Columbia River are included in a "viewshed," which
may extend inland from the river from 0.25 to approximately 2 miles. All property in the scenic
area is subject to strict development rules, which include a prohibition on any construction that
changes the "viewscape."

In 2000, Multnomah County had a population of 660,486. Physical growth was restricted due to
the establishment of an "urban growth boundary" that the state created in 1974 to reduce urban
sprawl. As a consequence, development was limited to specifically defined urban regions, and
most of the county residents (94 percent) lived in either of its two largest incorporated cities,
Portland (529,121) and Gresham (90,205). Residents (less than 35,000) in the unincorporated
area governed by the county were outside the urban growth boundary and spread out in suburban
and rural areas to the east and west of Portland within about 20 miles of the Columbia River.
Hazard mitigation activities established by the county affected those residents in the
unincorporated areas and not those in incorporated cities.

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[46] $4 million from the first two annual appropriations has been set aside as the county works out procedures for eligibility and
implementation. As of February 2005, the county was seeking public input to a draft of the program.

[47] The community of Edgewater was devastated by the 1998 tornado.
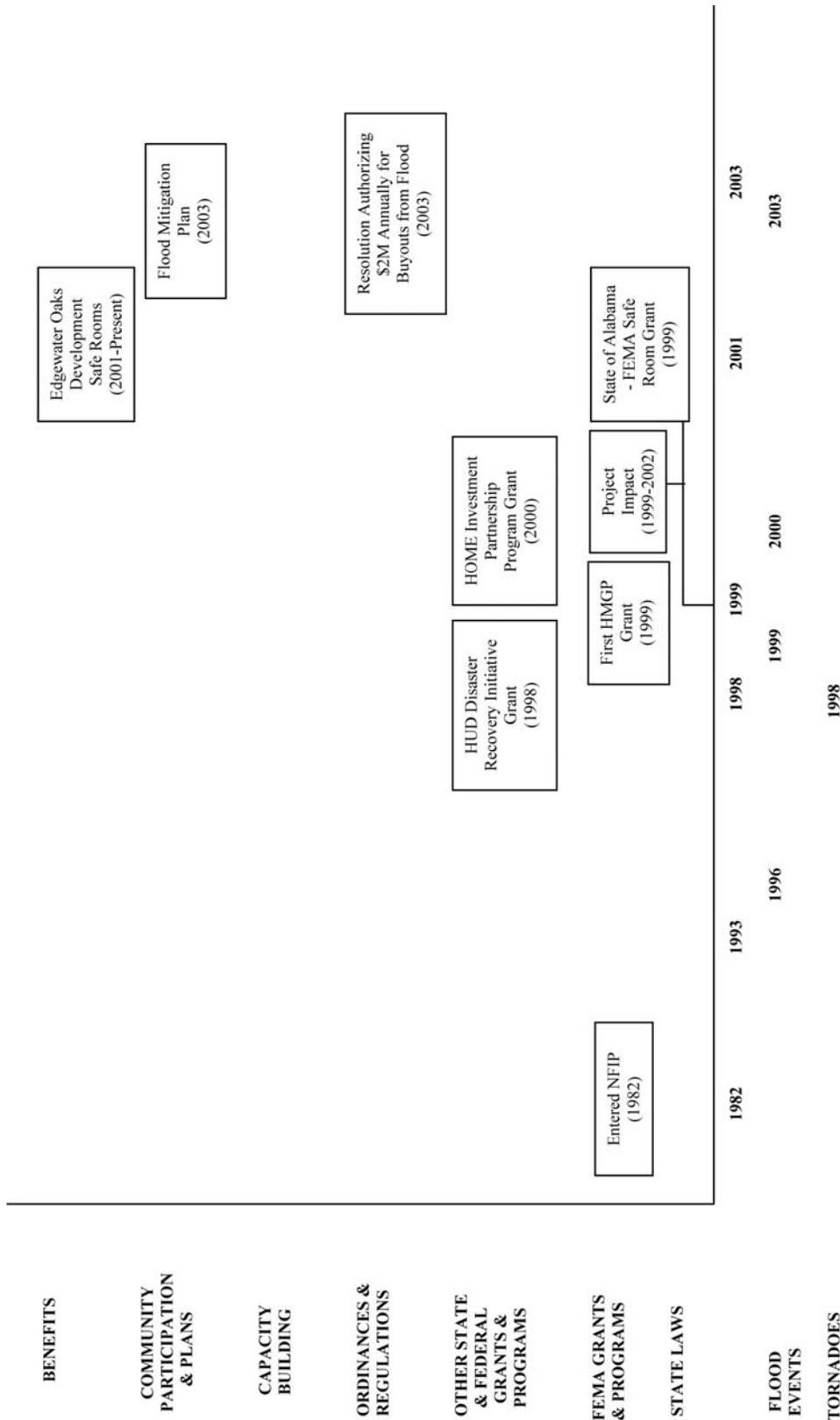
Figure 5-5   Activity chronology – Jefferson County, Alabama (unless otherwise indicated, activity dates above show start date).

Multnomah County had joined the National Flood Insurance Program in 1982 and adopted the required ordinances regulating construction in the floodplain; until joining Project Impact in 1999, the county has not developed any additional hazard mitigation programs. (See the discussion of Project Impact below.) Interviewees in the field stated that the City of Portland had a significant program and there was no need to duplicate it.

Seven telephone interviews were conducted with persons in Multnomah County. When asked about the community's hazard mitigation plan, most were either noncommittal or negative. One interviewee said "Quite frankly, I don't think it's very good." Another said "We really do not have one." Finally, a third interviewee said "They're working on their plan. I don't think they have the resources to focus on it as much as [Portland]."[48]

In 1996, severe storms caused a landslide and debris flow in the Dodson/Warrendale area of eastern Multnomah County, which is located in an unincorporated section of the county. Even though the area was lightly populated, the landslide damaged several houses and just missed others. After the storms became a Presidentially declared disaster, FEMA approved two HMGP awards to the county for just under $1 million to purchase either damaged structures or some that were barely bypassed by the debris flow (Table 5-8).[49]

5.2.6.1 Hazard Mitigation Grants Awarded to Multnomah County, Oregon

Both HMGP grants shown in Table 5-8 were to buyout properties in the Dodson/Warrendale area of the county. Nineteen properties in this area, all located in the Columbia River Gorge National Scenic Area, were deemed eligible to be purchased. Eleven filed applications, but funds were sufficient only to purchase six. Attempts to secure additional FEMA funding were unsuccessful.

Only one of the telephone interviewees was "extremely familiar" with these HMGP grants, and four others claimed having only limited knowledge. They provided no substantive comments on either grant.

Before the six purchased structures were demolished, all were first used in Special Weapons and Tactics and Crisis Emergency Response teams training. One house also was used in the County Fire Department's "Burn to Learn" program.

One consequence of the landslide and efforts of FEMA and local emergency management officials to encourage owners to sell their homes was the evacuation of a school that suffered minimal damage during the landslide. The local school district closed the school and relocated the students to nearby schools outside the landslide area.

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[48] Telephone interviewees were also asked about the community's risk of natural hazards. Respondents said the county was at high risk of earthquake (mean = 8.1 on a ten-point scale; standard deviation = 1.7), high risk of flood (mean = 7.1; standard deviation = 1.8) and moderate risk of wind (mean = 4.9; standard deviation = 2.3). Because most of the county is incorporated and not subject to county emergency management activities, the responses concerning risk should be taken with some caution. NFIP statistics show that there were just 379 insurance policies in force in the unincorporated area of the county as of December 31, 2003 and, in the 26 years between and including 1978 and 2003, FEMA paid just 59 claims totaling just over $1 million.

[49] FEMA's share was 75 percent; the local share, 25 percent, came from Community Development Block Grant (CDBG) funds that were approved by Congress in the Supplemental Appropriations Bill of 1996 (Title II of Public Law 104-134) and subsequently awarded to Multnomah County.

A significant debris flow occurred in 2002. There was no damage to any residence or other structures.

Table 5-8 FEMA hazard mitigation grants awarded to
Multnomah County, Oregon[1]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1099	0005	Acquisition: Dodson – Warrendale	Acquisition of private real property (structures and land) – riverine	4/11/97	803,499	602,587
1160	0020	Multnomah County acquisition	Acquisition of private real property (structures and land) – riverine	Unknown	18,311	13,733

[1]Data for this table comes from the NEMIS database.

5.2.6.2 Project Impact

Multnomah County received a Project Impact grant of $300,000 in 1999.[50] The genesis of the county's proposal was unusual. Originally two groups representing East Multnomah County and the Johnson Creek Watershed applied independently to the state to be considered for a Project Impact grant. In the fall of 1998, they decided to join forces and asked Multnomah County to submit a joint application on their behalf, which was approved.

After the grant was awarded, Multnomah County entered into an Intergovernmental Agreement with the City of Portland to transfer $150,000 or 50 percent of the Project Impact grant to the City of Portland to manage the Johnson Creek Watershed portion. The City of Portland wanted control of the project so it could be integrated into a Community Rating System application that would be submitted in 2001, thereby improving the city's chance of receiving a higher rating.[51] Multnomah County considered this a "pass through" project and did not maintain detailed files on it. Because hazard mitigation activities undertaken by the City of Portland were not evaluated in this study, details of the Johnson Creek Watershed portion of the Project Impact grant were not investigated.

Multnomah County spent the remaining $150,000 working with local K-12 schools to prepare 72-hour emergency preparedness kits, establishing a Business Continuation and Mentoring Program, establishing Neighborhood Emergency Response Teams, completing a flood hazard information web site, and retrofitting an existing building for earthquake to demonstrate the methods employed as an educational model for contractors and engineers. However, before Project Impact ended in 2002, Multnomah County suffered a major budget shortfall and had a change in administration. Except for the continuation of the school's commitment to continuing

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[50] See Appendix Q for a complete description of Multnomah County's Project Impact grant.

[51] On September 26, 2001, FEMA announced that Portland had received a Class 6 rating (on a 10-point scale the higher the flood protection activity, the lower the rating). At the time, this was one of the best ratings nationwide.

to prepare 72-hour emergency preparedness kits, the Project Impact initiatives were discontinued and the web site was shut down.

Telephone interviewees and those interviewed in the field were more familiar with Project Impact than the HMGP grants. As a group, the interviewees suggested that Project Impact had some positive effects on the county. One stated that "it brought people to the table that had never been to the table before." One thought Project Impact stimulated private sector mitigation. Similarly, one thought it permitted open communications between members of the business community that led to the development of many business continuity plans. Two persons believed it provided public education about risks and risk reduction options. One said that NERT trained many people in emergency response, increasing the capacity of the county to respond to potential disasters. And the retrofit building, nicknamed the "Bates Motel," was believed by some to have instructed the majority of contractors and engineers in the building community in earthquake retrofit methods.

On average, telephone respondents did not think Project Impact had been particularly successful in reaching its major objectives (mean = 6; standard deviation = 2.3). Since deciding not to pursue activities begun under Project Impact, Multnomah County also has decided not to establish a Citizen Corps. Interviewees said that the county did not want to incur costs that would duplicate efforts in Portland and Gresham.

5.2.6.3 Activity Chronology

An activity chronology was created for Multnomah County that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-6).

5.2.7 City of Orange, California

The City of Orange, California, is located approximately 32 miles southeast of Los Angles and is just south of Anaheim in Orange County. It was incorporated in 1888. At that time it was just 3.1 square miles. The small town was constructed around a central Plaza, called "Old Towne, Orange," which still exists today. Many of the original structures are still standing.

The city remained a small town until the end of World War II. At that time, three events occurred that caused a growth boom: returning servicemen and their families moved to the area, the southern California freeway system being constructed was turning out-of-the-way real estate into prime locations, and the city began to annex land where future development could occur. As a result of these events, the City of Orange expanded from 3.8 square miles and a population of 10,027 in 1950 to 23.9 square miles and a population of 128,821 in 2000.

Although the City of Orange has never experienced major flood or earthquake damage, hazard mitigation in the city has focused on preventing flooding near the Santa Ana River, which runs through the city, and the earthquake retrofit of older buildings. Flood mitigation has been almost entirely the concern of the U.S. Army Corps of Engineers, which has controlled the river's flow

BENEFITS

COMMUNITY
PARTICIPATION
& PLANS

CAPACITY
BUILDING

ORDINANCES &
REGULATIONS

OTHER STATE
& FEDERAL
GRANTS &
PROGRAMS

FEMA GRANTS
& PROGRAMS

STATE LAWS

FLOOD
EVENTS

Entered NFIP (1982)

First HMGP Grant (1997)

Project Impact (1999-2002)

1982   1996   1997   1999
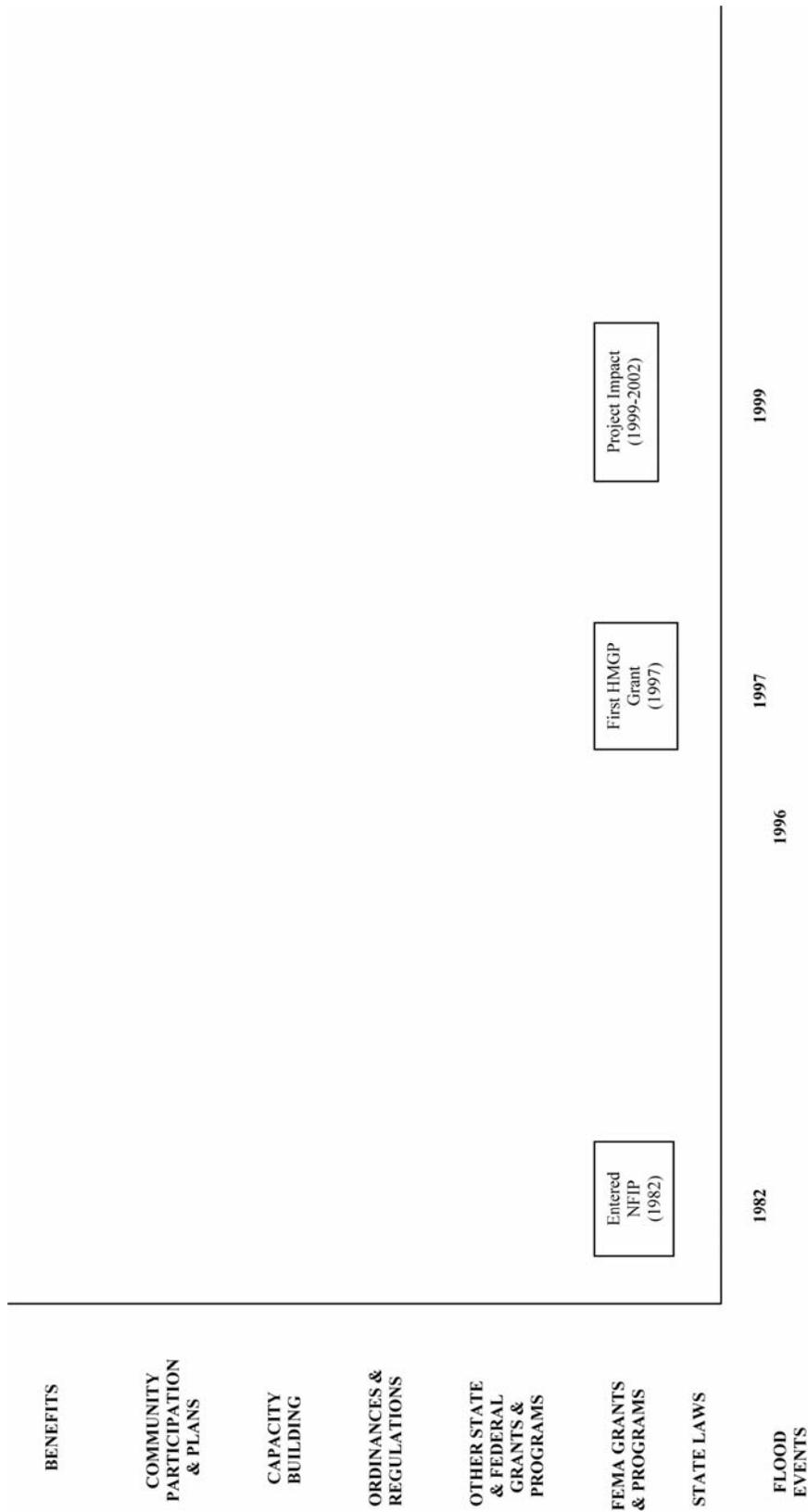
Figure 5-6 Activity chronology – Multnomah County, Oregon (unless otherwise indicated, activity dates above show start date).

through the city with the Prado Dam, built upstream of the city. According to one of the engineers in the Department of Public Works, recent improvements to the U.S. Army Corps of Engineers flood prevention structures have taken all of the existing buildings out of the 100-year floodplain. The risk from flood is now considered to be low. That opinion is backed up by NFIP data. According to information located on the FEMA website, from 1978 through 2003, FEMA paid just 11 flood insurance claims totaling $57,000.[52]

Despite the fact that the city has had little experience with natural hazards, the five telephone interviewees think the City of Orange is at high risk from earthquake (mean = 8.4 on a 10-point scale, standard deviation = 1.1) and at moderate risk from wind (mean = 6, standard deviation = 0.7) and flood (mean = 5.6, standard deviation = 1.9). Four of the five believed the city has a hazard mitigation plan, but none were particularly knowledgeable about its contents. One said "We're required to have various elements in our plan. We are updating. We do emergency training regularly." That person finished his comments with the following that seems to describe the city's history: "We only had to operate our EOC twice in the past 10 years." And another respondent said "I live in the city and I feel we're safe."

Earthquake retrofit began after the state legislature passed Senate Bill 547, the URM Building Law of 1986, mandating communities to inventory their unreinforced masonry buildings.[53] The City of Orange completed its survey in early 1990 and identified approximately 60 such buildings in the city, most located in Old Towne.[54] The city council then adopted Ordinance 7-92, which established minimum standards for structural seismic retrofit. Realizing that the cost of the retrofit might be prohibitive to individual building owners, the city council adopted Resolution 8010, which outlined their intent to create a URM financial assistance program.

The URM financial assistance program consisted of two phases. In Phase 1, the city hired an outside structural engineer to prepare engineering assessments and cost estimates to complete improvements to seismically retrofit identified properties. A total of $400,000 was allocated to the task; but actual expenditures were just $175,000. In Phase 2, the city provided $2,000,000 in grants equal to 45.98 percent of project costs to individual property owners to undertake the necessary improvements. Actual expenditures totaled approximately $1,700,000.

Approximately 50 property owners initially completed improvements under the program, which had a sunset date of December 1998. One additional property owner was allowed to complete improvements after the sunset date, bringing the total number of improved properties to 51 or 85 percent of the eligible buildings.

Following the 1995 Northridge earthquake, which caused no appreciable damage in the City of Orange, all communities were asked by the state Office of Emergency Services to submit proposals for FEMA HMGP awards to mitigate earthquake deficiencies in their public buildings. Five proposals submitted by the city were approved (Table 5-9).

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[52] The City of Orange entered the NFIP in 1987. According to informants, it adopted the required floodplain building codes of the NFIP and the state of California.

[53] Like other cities in California, the City of Orange has adopted seismic building codes for the construction of new buildings because they were required by the state.

[54] The history of the URM inventory and subsequent retrofit of most of the identified URM buildings is described in a memo entitled "URM Update" from the Acting Economic Development Director to the City Manager, January 9, 2004.

**Table 5-9 FEMA hazard mitigation grants awarded to the
City of Orange, California[1]**

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1008	3010	Retrofit of city yard warehouse – Phase 1 structure evaluation	Structural retrofitting / rehabilitating public structures – seismic	6/23/98	229,226	171,957
1008	3216	Structural and nonstructural retrofit of city hall	nonstructural retrofitting / rehabilitating public structures – seismic	6/18/98	99,851	74,888
1008	3217	Fire department headquarters - City of Orange	Feasibility, engineering and design studies	6/5/98	206,163	123,103
1008	3218	Retrofit of city yard garage/Phase 1 structural evaluation	Feasibility, engineering and design studies	6/17/98	432,465	324,349
1008	3219	Structural retrofit of water plant	Feasibility, engineering and design studies	6/30/98	207,456	155,592

[1]Data for this table comes from the NEMIS database and files from the City of Orange

5.2.7.1 Hazard Mitigation Grants Awarded to the City of Orange, California

The five HMGP grants awarded to the city included the retrofit of the city yard warehouse, city hall, fire department headquarters, the city yard garage, and the main water plant (Table 5-9)[55]. Three projects, the retrofits of the city yard warehouse, the city yard garage, and the water plant, were completed before the end of 1999. However, the other two projects, the retrofits of city hall and the fire department headquarters, had to be abandoned following initial design studies completed by consulting engineers when the projected costs far exceeded the estimated costs that were used to determine the amounts of the awards and FEMA would not amend the awards to reflect the additional costs.[56] The City of Orange officials decided the costs were too high for them to bear alone. As was discovered in the field visit to the City of Orange, one respondent describing the city hall project pointed out "This project never was completed because the estimate we got was four times the estimate FEMA had and the city could not afford the costs."

Of the five persons interviewed by telephone in the City of Orange, all five had some knowledge about the retrofit of the city hall, three about the retrofit of the fire department headquarters, five about the city yard warehouse, five about the city yard garage, and five about the water plant. "Reducing infrastructure damage" was thought to be the major objective of all five activities by all respondents who had an opinion with the exception of one respondent who thought the major objective of retrofitting the city yard warehouse was "reducing death, injury, and illness."

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[55] A yard is a location where vehicles and other equipment are maintained.

[56] The discrepancy between the initial estimated costs and costs derived from consulting engineers appears to be due to the process used by the City of Orange to arrive at the initial estimated costs. In a letter from the City's Emergency Services Coordinator to the California Office of Emergency Services dated March 18, 1998, the City of Orange agreed to participate in a "technical assistance program available for structural evaluations" provided by FEMA at no cost to the City to determine the cost of retrofitting City Hall. It is noted in the letter that "this is not a design and engineering but a building analysis to help FEMA evaluate our application." Apparently the "free" analysis was not adequate.

In spite of the fact that the City of Orange abandoned the retrofit of the city hall and the fire department headquarters because of high cost and no additional assistance from FEMA, the five respondents thought the five projects had been quite successful with mean scores on a scale of 1 to 10 that ranged from a low of 7 for the retrofit of city hall to a high of 8.67 for the fire department headquarters, city yard garage, and water plant. When asked to comment on specific HMGP grants, one said about the city yard warehouse "Those buildings are better able to withstand a major earthquake – our fire trucks and police cars are in those buildings and they are essential."

Since the cancellation of the two projects, the city has decided that it would be more prudent to construct a new city hall instead of retrofitting the old one. The new building would be larger, which would accommodate a larger staff, and the cost of the new, larger building would be about the same as the cost of retrofit. The city also began to set aside funds to complete the retrofit of the fire department headquarters and build the new city hall; however, last year, the funds were diverted for the construction of a new city library.

5.2.7.2 Project Impact

The City of Orange did not participate in Project Impact.

5.2.7.3 Activity Chronology

An activity chronology was created for the City of Orange that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants (Figure 5-7).

5.2.8 Tuscola County, Michigan

Tuscola County is a rural county with a relatively stable population of about 58,000. It is 914 square miles in size and is located in east central Michigan just north of Flint and just east of Saginaw. Approximately 10 percent of the land is covered by water, and the northern border of the county is the southern shore of Lake Huron. There are 34 incorporated towns or villages in the county.

The county is subject to flooding and tornado winds. Eleven people were interviewed by telephone in Tuscola County. As a group, they thought that the county was at high risk from floods (mean = 8.7; standard deviation = 1.0) and moderate risk from wind (mean = 5.8; standard deviation = 0.81).[57]

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[57] Responses were on a 10-point scale ranging from a low of 1 to a high of 10.
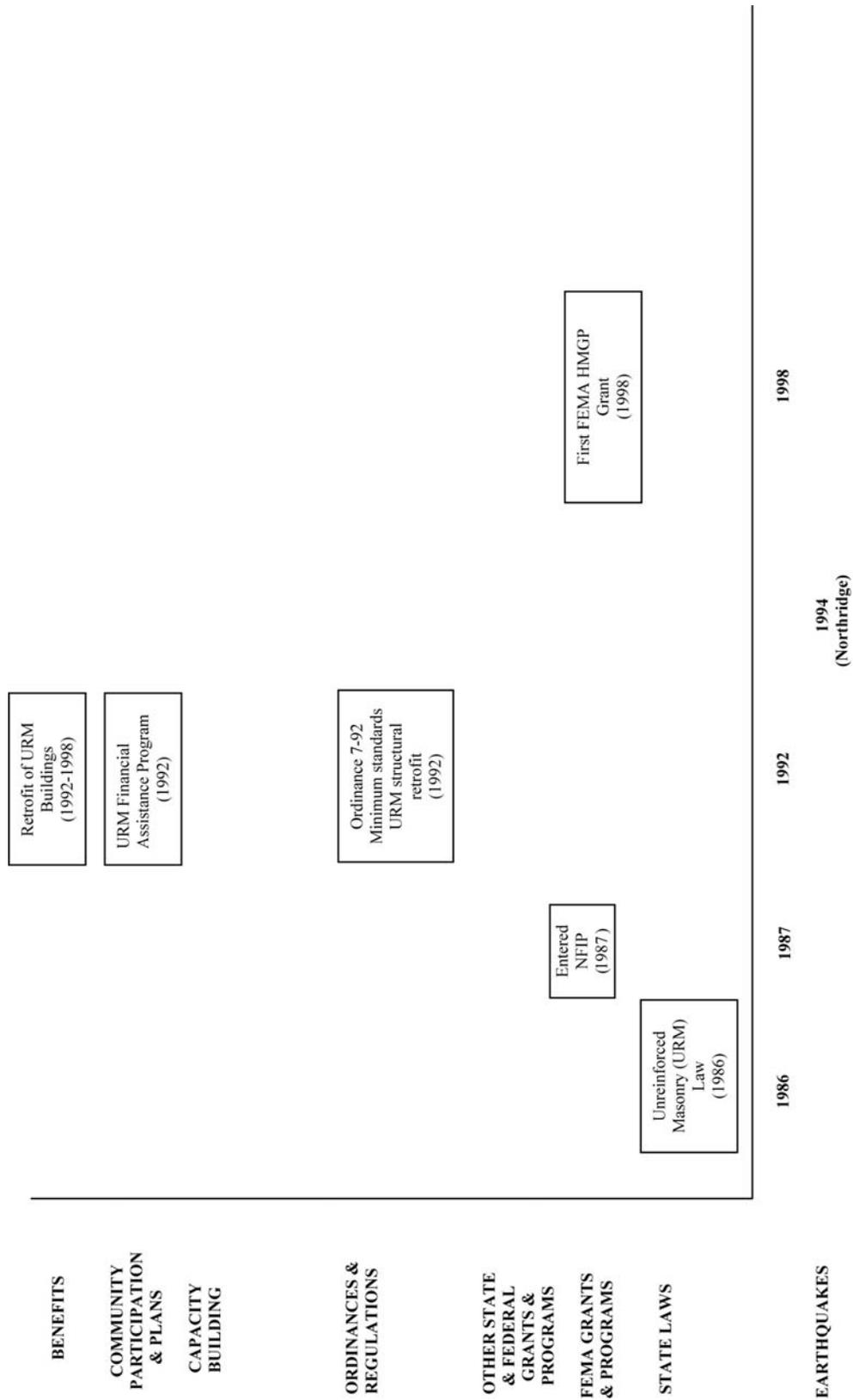
Figure 5-7 Activity chronology – City of Orange, California (unless otherwise indicated, activity dates above show start date).

Because the Michigan constitution affirms that all property in the state must be included in incorporated municipal jurisdictions, municipalities, not counties, are responsible for land use and other decisions affecting hazard mitigation. The only exceptions are those powers specifically granted to counties that are denoted in the constitution.

According to the Michigan Drain Code of 1956, counties are responsible for all drainage activities, including flood mitigation. Counties have the authority to develop flood mitigation policies, but counties and municipalities must work cooperatively to achieve compliance.

In Michigan, a drain commissioner is elected in each county to manage drainage activities permitted under the Drain Code of 1956.[58] The commissioner acts autonomously and is legally responsible for all drainage initiatives taken in the county. Consequently, a county's flood mitigation program is directly dependent on the actions of the drainage commissioner. The current drain commissioner in Tuscola County is a strong supporter of flood mitigation and has devoted considerable effort to reducing potential flood damages in highly vulnerable locations such as the Village of Vassar. Since 1997, following a devastating 1996 flood, the drain commissioner and the village have worked together to eliminate small flood events that occur several times a year.

Because rivers cross county boundary lines and may drain outside their borders, drain commissioners can become involved with flood mitigation activities in neighboring counties and municipalities outside their jurisdictions. As will be discussed below, two FEMA hazard mitigation grants awarded to the Tuscola County Drain Commission involved such multijurisdictional activities.

As noted above, the ultimate management of hazards is in the hands of the incorporated towns and villages. In Tuscola County, that would entail an examination of 34 distinct communities, something far beyond the resources of this study and the charge to limit the eight community studies to eight single communities. Therefore, no detailed study of the hazard mitigation experiences, properties at risk, or existing plans of all the municipalities has been conducted.[59] What is clear, however, is that a number of communities in the county have a significant flood risk that has led the Tuscola County drain commissioner to apply for HMGP grants.

When asked about whether Tuscola County had a hazard mitigation plan, one telephone respondent said "Every county is putting together a hazard mitigation plan, a FEMA directive in order to be eligible for grants. [We] don't have a plan currently from a county-wide perspective. It is more about enforcing building codes. [The Village of] Vassar actually has a plan."

Because the HMGP grants awarded to the Tuscola County Drain Commission most affected the Village of Vassar, information on its flood risk and past experiences was sought. Vassar was organized around a sawmill in 1849 and incorporated in 1851. Flooding from the Cass River and the Moore Drain whose confluence is near the center of the city has been a significant problem since at least 1900. Many commercial structures that have been repeatedly damaged by floods

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[58] One of the interviewees explained that before statehood in 1837, Michigan could be characterized as being "swampy." After statehood, water needs and water hazards were such critical issues that county drainage commissioners were among the first elected officials in the state.

[59] A search for an existing county-wide study proved fruitless.

were constructed in the early 1900s and now comprise what Vassar citizens today consider a historic district. Within Vassar, the M-15 is a major commuter route with a bridge over the Cass River that has been flooded numerous times. M-15 is a transportation route for emergency services and flooding results in substantial detours for ambulances and other emergency service vehicles.

During the period from 1900 to 1947, several interviewees stated that the Village of Vassar transitioned from a lumber-based economy with some farming and commercial activities to a more agricultural economy with more commercial activities. As part of agricultural practices, the capacity and flow of the Cass River were modified. Farmers built ditches and used tiles to force runoffs into the Cass River so they could plow fields in the spring. These activities upstream of Vassar increased peak flows on the Cass River into the village.

Between 1947 and 1985, the Cass River flooded 14 times in Vassar. Many of these recorded floods were severe. Overflows of the Cass River began when the height of the river surpassed the expected height of a 5-year flood. As a result of a 1947 flood, Vassar citizens petitioned the U.S. Army Corps of Engineers to look at possible solutions to the flood damages in Vassar caused by the Cass River. The U.S. Army Corps of Engineers presented its first solution in 1951, but it was deemed too expensive for the community and thus not accepted because of the amount of the required local match.[60] Later proposals (1976, 1982) submitted by the U.S. Army Corps of Engineers met with similar fates again in part due to costs but also because of conflict between community constituencies regarding who would benefit from structural solutions and who would pay for them. Farmers and persons living outside the floodplain generally were reluctant to assume costs for structural solutions from which they might not directly benefit.

Although the three U.S. Army Corps of Engineers evaluations did not result in a solution acceptable to the community, they did result in clarifying the relationship between the Moore Drain and the Cass River. It was found that in severe floods, the Moore Drain overtopped before the Cass River. Two informants said that this finding led a private engineering firm to propose a solution in the late 1970s that encompassed both waterways. It was not implemented at that time.

No counties in Michigan, including Tuscola, have entered the National Flood Insurance Program. Municipalities, not counties, have jurisdiction over structures within their boundaries and are responsible for regulating construction in floodplains. Thus, municipalities may join the NFIP, but counties are not eligible. Normally, a consequence of not being in the NFIP is not being eligible for public assistance or mitigation grants following floods. However, in this situation, counties are eligible to apply for and receive flood mitigation grants.

The Village of Vassar joined the NFIP in 1977 and enacted its first floodplain regulations. At the same time, the state of Michigan began to pass floodplain laws that were stricter than those of the NFIP and mandated their local adoption. According to one informant, "what could once be constructed in the floodway was no longer possible."

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[60] The U.S. Army Corps of Engineers proposal was $7 million in 1951 dollars. The local match was 5 percent of the total.

Between 1985 and 1996, there were five floods, two of which, 1985 and 1996, were severe. During this time, the state of Michigan further tightened its floodplain regulations. Construction in floodways was virtually prohibited and buildings that were damaged at more than 50 percent of their value, if rebuilt, had to meet current building code regulations.

As a result of a decision in 1984 by FEMA to acquire private homes following floods under the authority of Section 1362 of the National Flood Insurance Act, FEMA's former Federal Insurance Administration started a program to purchase substantially damaged houses (i.e., those that suffered damage exceeding 50 percent of the value of the structure. One respondent reported that, in 1988, nine residences were acquired directly from their owners, not using the community as an intermediary.[61] Over time, Vassar officials realized that those who sold residences did not necessarily stay in the community boundaries and people who vacated small businesses because of the cost of rebuilding did not reopen. One consequence was the loss of tax revenues, a major source of local income.

After the 1996 flood, increased recognition of how severe flooding impacts residences, the historic business district, and the delivery of emergency services within the community combined with increasingly strict state laws regulating floodplains, continuing revenue losses associated with purchasing damaged property, and some shift of political power away from agriculture led the citizens of Vassar and landowners in Tuscola County to petition the county drain commissioner to assist in finding a solution to the flooding problem. According to the Drain Code of 1956 as amended, the drain commissioner can write grants, manage grants, and also provide special assessments to offset funding of flood-related projects. Following these discussions, the drain commissioner worked with concerned citizens and local officials to submit proposals for grants from the Hazard Mitigation Grant Program (Table 5-10).

Telephone interviewees explained why partnerships between municipalities and the county were important. One said that "towns had more damage than their budgets could tolerate." Another commented that "mutual cooperation from all entities and funding would entice property owners to enter." A third said that the common goal is to "reduce flooding, improve the infrastructure, and reduce floods on highways, farms, and homes." A fourth believed there was a "trickle down effect. Once there was one successful project, then others jumped on board."

5.2.8.1 Hazard Mitigation Grants Awarded to the Tuscola County Drain Commission

The Tuscola County Drain Commission received four HMGP grants between 1998 and 2004 (Table 5-10). The first was to install culverts in the Coleman Drainage District. The second was to construct detention basins as part of the Reese Intercounty Drain. The third was a feasibility study of the Moore Drain. The fourth was a major structural project

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[61] The Village of Vassar received Flood Mitigation Assistance grants between 1998 and 2001 for the acquisition and elevation of homes in the floodplain.

Table 5-10 FEMA hazard mitigation grants awarded to Tuscola County, Michigan[1]

Disaster Number	Project Number	Title	Type	Date Approved	Approved Net Eligible Project Cost ($)	Federal Share Obligated ($)
1128	0021	Coleman Drainage District	Stormwater management - culverts	3/2/98	165,167	123,500
1181	0053	Tuscola County Drain Commission – relief branches of the Reese Intercounty Drain	Stormwater management – detention/retention basins	6/23/00	400,000	300,000
1226	0016	Tuscola County Drain Commission – flood study	Feasibility, engineering, and design studies	6/3/99	140,000	105,000
1346	0029	Moore Drain Flood Mitigation Project	Stormwater management – diversions	1/26/04	2,383,000	1,787,000

[1]Data for this table comes from the NEMIS database

to reduce flooding caused by overflows from the Moore Drain. It followed the findings of the previous study.

The first two grants involved jurisdictions both inside and outside Tuscola County. Even though the grants were written by and monitored by the Tuscola County Drain Commission, the actual management of the projects entailed multijurisdictional issues that were beyond the scope of this study, which was to evaluate hazard mitigation projects conducted by single jurisdictions. Consequently, these grants have not been evaluated in this study. The third and fourth grants affected one community wholly within Tuscola County and are evaluated.

The Moore Drain Flood Mitigation Project has only just begun. As such, there will be no test of its effect until is finished. However, work on the project has inspired some to redevelop the downtown. Some building owners believe that the flood risks will be tolerable so investment is justified.

Of the nine people interviewed by telephone who knew about the feasibility study for the Moore Drain, most reported that its main objective was obtaining "new knowledge about hazards and their effects." The respondents thought the objective was met (mean = 8.5; standard deviation = 2).

Seven telephone interviewees knew about the Moore Drain Flood Mitigation Program. Among the most knowledgeable respondents, the major objectives were identified as "reducing stress and trauma" (number of respondents = 1) and "reducing property damage" (number of respondents = 3). One respondent suggested there was "a psychological impact. There used to be a flood pole [which was] watch[ed] everyday. Watch water climb up the pole. It must really influence people, stressful."

Speaking of hazard mitigation in general, one interviewee commented: "There are only 55,000 people in the county. Because of such a small population, we wouldn't be able to complete projects if not for the hazard mitigation process."

Not everyone agreed with this statement. One person said: "Mitigation is something Vassar has fought over tremendously. A river and a drain run through downtown Vassar. Some say move

the downtown, and some say move the water. Many people don't want government telling them what they can build."

5.2.8.2 Project Impact

Tuscola County did not participate in Project Impact.

5.2.8.3 Activity Chronology

An activity chronology was created for Tuscola County that illustrates the relationship between FEMA mitigation grants, community mitigation activities, and synergistic activities encouraged by the FEMA grants. The community activities in the chronology only refer to the Village of Vassar (Figure 5-8).

5.3 Mitigation Activities Undertaken

This section begins by summarizing the FEMA-funded mitigation activities performed in each community. Next, synergistic activities and effects are identified and then summarized for the eight communities evaluated

5.3.1 FEMA-Funded Mitigation Activities

Based on the NEMIS database and supplemented by local field data, Table 5-11 summarizes specific HMGP grant expenditures (2002$) in terms of total mitigation cost and the amount that FEMA contributed to the total cost. Total costs include local maintenance costs.

Based on field data, Table 5-12 summarizes expenditures for Project Impact communities. Five communities received Project Impact grants. Total costs include the cost to FEMA and local governmental expenditures beyond those required by the cost-sharing agreements but do not reflect the full range of private sector donations.

5.3.2 Synergistic Activities or Effects

Synergistic activities are activities or effects that follow or accompany the award of FEMA grants for project mitigation or process mitigation activities or the strong expectation that a grant would be awarded, that reduce risks (or increase benefits of risk-reduction activities) from floods, earthquakes, and severe winds. These activities are not funded by FEMA. In Section 2.5.2, three types of synergistic activities or effects were defined: spin-off activities, collateral risk-reduction activities, and spill-over effects. Table 5-13 summarizes the synergistic activities or effects identified in the eight communities.
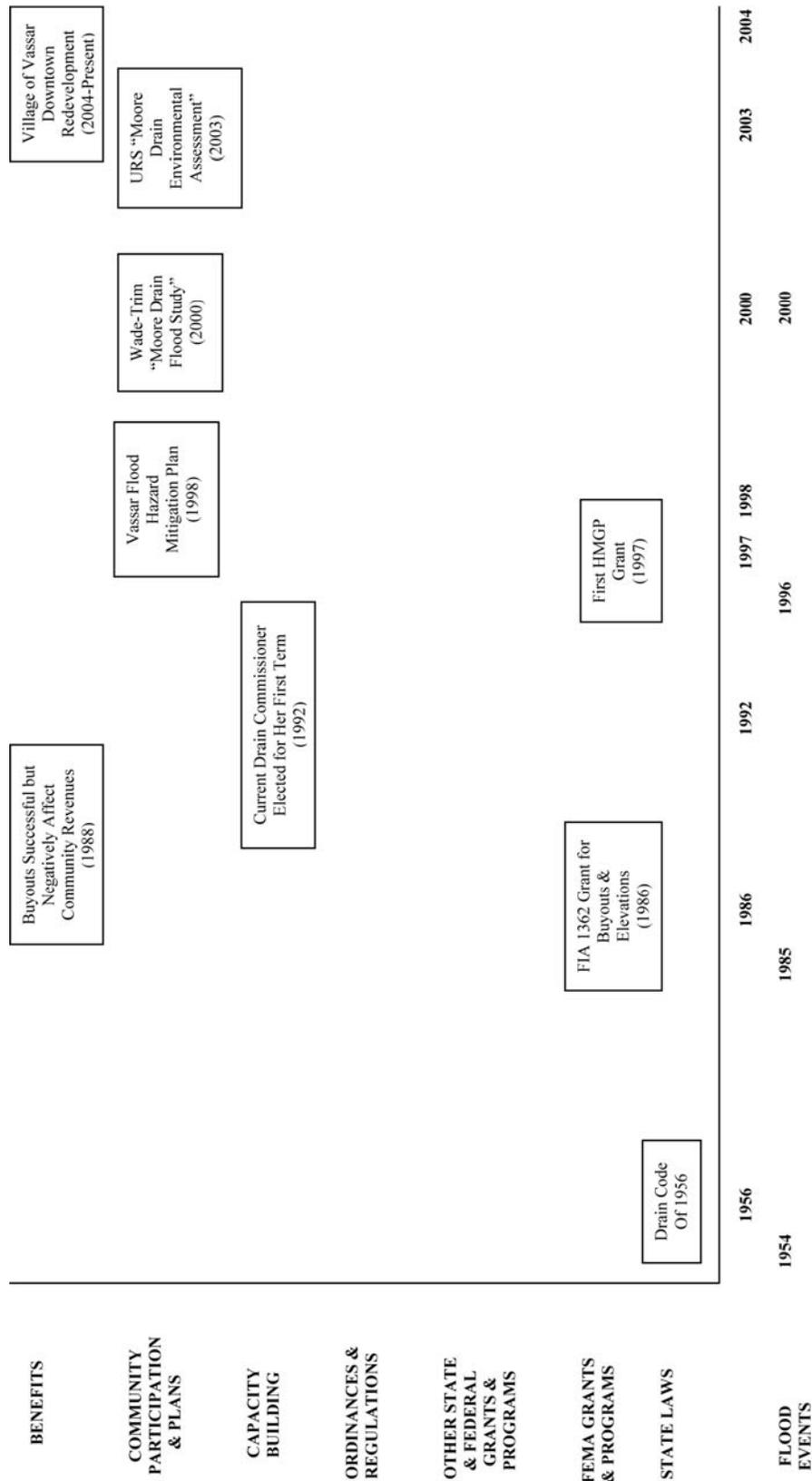
Figure 5-8 Activity chronology – Tuscola County, Michigan (unless otherwise indicated, activity dates above show start date).

Table 5-11   Summary of FEMA HMGP grants for eight communities studied

Community	Description of Mitigation Activity	Total Cost (2002$M)[1,2]	FEMA Share of Total Cost (2002$M)[2]
Freeport, New York	Elevating streets	2.76	2.07
	Building Elevations	2.36	1.77
	Total—Freeport	5.11	3.83
Hayward, California	Seismic Retrofit of Fire stations	5.11	2.60
	Sodium Hypochlorite Wastewater facility	1.84	0.50
	Total—Hayward	6.95	3.10
Horry County, South Carolina	Hazard mitigation plan	0.16	0.08
	Purchase emergency generators	0.05	0.02
	Shutter retrofits	0.26	0.20
	Other wind retrofits	0.45	0.33
	Buyouts and elevations	6.53	4.90
	Total—Horry County	7.45	5.54
Jamestown, North Dakota	Lift station	0.05	0.04
	Oxbow dike	0.60	0.45
	Total—Jamestown	0.65	0.49
Jefferson County, Alabama	Acquisition Grants	3.17	2.38
Multnomah County, Oregon	Acquisition grants	0.91	0.68
Orange, California	City garage retrofit	0.27	0.20
	City yard retrofit	0.27	0.20
	Water pump station retrofit	0.32	0.24
	Total— Orange, CA	0.86	0.65
Tuscola County, Michigan	Acquisitions	0.12	0.04
	Moore Drain structural mitigation	2.40	1.80
	Total—Tuscola County	2.52	1.84

[1] May include local government maintenance costs.

[2] Sums may be off due to rounding.

Table 5-12 Project Impact costs for five communities

Community	Total Cost (2002$K)	FEMA Cost Share (2002$K)
Freeport, New York	626	162.8
Horry County, South Carolina	160	120
Jamestown, North Dakota	314.7	236.0
Jefferson County, Alabama	314	236
Multnomah, Oregon	150	113

* Excludes donations, but includes annual local government maintenance costs for completed projects.

Table 5-13 Summary of synergistic activities or effects[1]

Community	Spin-off Activities	Collateral Activities	Spill-over Effects
Freeport, New York	None found	Elevating streets	Development of the commercial Nautical Mile
Hayward, California	Seismic retrofit of tilt-up and unreinforced masonry buildings	None found	Impacts of seismic retrofit of commercial buildings
Horry County, South Carolina	Wind code development and implementation	None found	None found
Jamestown, North Dakota	School storm drain improvement	None found	None found
Jefferson County, Alabama	Saferooms in new residential development; local expenditures in additional buyouts	None found	None found
Multnomah County, Oregon	None found	Evacuated school	None found
City of Orange, California	None found	Seismic retrofit of downtown un-reinforced masonry buildings	None found
Tuscola County, Michigan	Increased level of elevations by residential owners; and subdivision grading by developer	None found	Downtown redevelopment

[1]Synergistic activities are activities or effects that follow or accompany the award of FEMA grants for project mitigation or process mitigation activities or the strong expectation that a grant would be awarded, that reduce risks (or increase benefits of risk-reduction activities) from floods, earthquakes, and severe winds. These activities are not funded by FEMA.

5.4 Benefit-Cost Results

This section summarizes the calculation of benefit-cost ratios for HMGP activities, Project Impact grants, and spin-off activities. In addition, the results of a cost-effectiveness analysis of FEMA-funded process activities are also discussed. For community studies, the basic unit for analysis is ultimately the community itself. Thus, the focus is on those benefits and costs that have a significant impact on overall community net benefits.

5.4.1 Hazard Mitigation Grant Program Grants

Table 5-14 provides a summary of the costs, benefits, benefit-cost ratios and benefit-cost ratio ranges for all the major HMGP grants for project mitigation activities identified in the community studies. This table breaks these values down by mitigation activity and community. Frequently, multiple grants are used to buy out or elevate structures that were damaged in a single flood. In Horry County, for example, one grant (1243-0007) funded the acquisition of two properties; a second grant (1299-0014) funded the elevation of four houses, and a third grant (1299-0021) funded the acquisition of additional properties. In this case, these three grants are grouped together with two disaster 1299 supplemental grants (4299-0003 and 4299-0005) under a single mitigation activity descriptor in Table 5-14.

**Table 5-14 Summary of costs, benefits, benefit-cost ratios and ranges
by HMGP project grant activities and by community**

Community	Brief Description of Mitigation Activity	Total Costs (2002 $M)	FEMA Costs (2002 $M)	Best Estimate		
				Benefits (2002 $M)	Benefit-Cost Ratio	BCR Range
Freeport	Street grading / elevations	2.76	2.07	6.52	2.4	0.19 – 9.6
	Building elevations	2.36	1.77	13.5	5.7	0.18 – 16.3
	Freeport Totals	*5.11*	*3.83*	*20.0*	*3.9*	*0.19 – 12.7*
Hayward	Fire stations	5.11	2.60	38.1	7.5	1.65 – 15.0
	Wastewater facility	1.84	0.50	12.8	7.0	2.84 – 17.2
	Hayward Totals	*6.95*	*3.1*	*50.9*	*7.3*	*1.96 – 15.6*
Horry County	Hazard mitigation plan	0.16	0.08	0.21	1.25	–
	Purchase emergency generators	0.05	0.02	0.05	1	–
	Shutter retrofits	0.26	0.20	2.27	8.6	1.9 – 17.2
	Other wind retrofits	0.45	0.33	0.45	1	–
	Buyouts and elevations	6.53	4.90	13.19	2.02	0.44 – 4.04
	Horry County Totals	*7.45*	*5.54*	*16.16*	*2.17*	*0.55 – 4.2*
Jamestown	Lift station	0.05	0.04	0.63	11.8	0.8 – 43.2
	Oxbow dike	0.60	0.45	0.39	0.66	0.05 – 6.9
	Jamestown Totals	*0.65*	*0.49*	*1.02*	*1.57*	*0.11 – 9.7*
Jefferson County	Acquisition grants	3.17	2.38	5.71	1.8	0.4 – 3.6
Multnomah County	Acquisition grants	0.91	0.68	1.06	1.17	0.13 – 11.7
City of Orange	Garage retrofit	0.27	0.2	1.28	4.7	1.03 – 9.4
	Yard retrofit	0.27	0.2	0.31	1.16	0.13 – 4.6
	Pump station retrofit	0.32	0.24	0.15	0.46	0.1 – 1.6
	City of Orange Totals	*0.86*	*0.65*	*1.73*	*2.0*	*0.4 – 5.0*
Tuscola County	Acquisitions	0.12	0.04	0.18	1.72	0.76 – 3.4
	Moore Drain structural mitigation	2.40	1.8	31.30	13	2.9 – 26.0
	Tuscola County Totals	*2.52*	*1.84*	*31.48*	*12.5*	*2.8 – 24.9*

Data collected in the field included actual mitigation costs and information needed to estimate mitigation benefits. To the extent possible, these field data were used in conjunction with HAZUS®MH to estimate benefit-cost ratios. For example, HAZUS®MH was used to estimate the impact of earthquakes on fire stations and the possibility of fire following an earthquake; to develop damage estimates and plume contours for determining potential losses from an accidental chlorine release; to estimate the benefits of shutters in wind-prone regions; and to estimate the damage to buildings subject to various wind velocities and flood depths.

In many cases, HAZUS®MH was supplemented by other methods to estimate benefits. For example, the impact from chlorine release was estimated using models developed by Seligson et al. (1998) to supplement existing plume modeling capabilities in HAZUS®MH. Data from local communities based both on flood gauges and on 100-year flood depths of specific properties were used to estimate expected flood losses. The direct use of local data thus stands in contrast to the regional approach used in the benefit-cost analysis for flood-related acquisitions.

For safe room evaluations, many sources of data were used to construct a new method for assessing the frequencies of severe tornado wind velocities based on an historic account of tornadoes in the general region (Section 4.3.2).

If quantitative methods for calculating benefit-cost analyses could not be found or developed, benefit transfer methods (Section 2.3) were used. Thus, these methods were used to analyze the development of hazard mitigation plans and the assessment of benefits of some wind mitigation activities. In these cases, no sensitivity analysis was performed.

The sensitivity evaluations shown in Table 5-14, use extreme ranges of benefit-cost ratios that take into account factors that can affect these ratios significantly. These factors are also shown in Tables 5-15 and 5-16. Uncertainties in the following five major estimates are considered:

1. Frequency of occurrence of the pertinent hazard,
2. Casualty rates/costs,
3. Impacts of alternative discount rates,
4. Exposure, and
5. Clean-up costs.

Uncertainties used in estimating the frequency with which pertinent hazards occur are derived from the alternative, credible models that have been developed in the considerable ongoing research being conducted particularly on earthquakes, hurricanes, and floods. A factor of two (multiplying by 2.0 on the upside and by 0.5 on the downside) is used based on results from earthquake probabilistic hazard modeling. A factor of two may underestimate uncertainties for hazards for which less research on frequency of occurrence has been conducted (Perkins, 2002; Harmsen, 2005; American Lifelines Alliance, 2002).

Uncertainties for casualty rates and cost are used for models for which HAZUS®MH is not wholly applicable. These uncertainty estimates cover special cases of debris flows and tornadoes.

Table 5-15 Downside factors used in uncertainty calculations for Table 5-14

Community	Brief Description of Mitigation Activity	Frequency of Occurrence	Casualty Rates / Costs	Discount Rate Impact	Exposure	Clean-up Costs
Freeport	Street grading / elevations	1.0 (Already lower bound)	1.0	0.44	0.5	0.36
	Building elevations	1.0 (Already lower bound)	1.0	0.44	0.2	0.36
Hayward	Fire stations	0.5	1.0	0.44	1.0	1.0
	Wastewater facility	0.5	1.0	0.81 (maintenance)	1.0	1.0
Horry County	Hazard mitigation plan	1.0	1.0	1.0	1.0	1.0
	Purchase emergency generators	1.0	1.0	1.0	1.0	1.0
	Shutter retrofits	0.5	1.0	0.44	1.0	1.0
	Other wind retrofits	1.0	1.0	1.0	1.0	1.0
	Buyouts and elevations	0.5	1.0	0.44	1.0	1.0
Jamestown	Lift station	0.5	1.0	0.78 (short life span)	0.5	0.36
	Oxbow dike	0.5	1.0	0.78 (short life span)	0.5	0.36
Jefferson County	Acquisition grants	0.5	1.0	0.44	1.0	1.0
Multnomah County	Acquisition grants	0.5	0.5	0.44	1.0	1.0
City of Orange	Garage retrofit	0.5	1.0	0.44	1.0	1.0
	Yard retrofit	0.5	1.0	0.44	0.5	1.0
	Pump station retrofit	0.5	1.0	0.44	1.0	1.0
Tuscola County	Acquisitions	1.0 (Already lower bound)	1.0	0.44	1.0	1.0
	Moore Drain structural mitigation	1.0 (Already lower bound)	1.0	0.44	0.5	1.0

Uncertainties in discount rates used and life-span of the mitigation project pertain chiefly to policy-level selection of discount rates. The base rate used here is 2 percent; however, in the recent past, 7 percent has been used. This higher discount rate reduces the present value of downstream benefits. At the same time, if there are significant downstream maintenance costs, a higher discount rate also will reduce the present value of these costs. In only one case (Jamestown), has the life span of mitigation been considered an uncertain factor.

Uncertainties about exposure result in part from limitations in field investigations conducted and the documents obtained. More extensive research might clarify the size of the population within a structure and the number of occupants exposed. In other instances, the field data do not adequately indicate the extent, if any, of process activities undertaken within the eight communities studied.

Uncertainties in clean-up costs result because expert judgment (oral communication, Oren Nelson, President of Nelson Brothers Construction Company, 2005) has been required to develop ranges of such clean-up costs. These ranges can be considerable for flooded basements and significant uncertainties can result from estimates of the savings that result, for example, from sandbagging.

Table 5-16 Upside factors used in uncertainty calculations for Table 5-14

Community	Brief Description of Mitigation Activity	Frequency of Occurrence	Casualty Rates / Costs	Discount Rate and / or Life Span Impact	Exposure	Clean-up Costs
Freeport	Street grading / elevations	2.0	1.0	1.0	2.0	1.0
	Building elevations	2.0	1.0	1.0	1.0	1.43
Hayward	Fire stations	2.0	1.0	1.0	1.0	1.0
	Wastewater facility	2.0	1.0	1.23 (maintenance)	1.0	1.0
Horry County	Hazard mitigation plan	2.0	1.0	1.0	1.0	1.0
	Purchase emergency generators	2.0	1.0	1.0	1.0	1.0
	Shutter retrofits	2.0	1.0	1.0	1.0	1.0
	Other wind retrofits	2.0	1.0	1.0	1.0	1.0
	Buyouts and elevations	2.0	1.0	1.0	1.0	1.0
Jamestown	Lift station	2.0	1.0	1.83 (life span)	1.0	1.0
	Oxbow dike	2.0	1.0	1.83 (life span)	2.0	1.43
Jefferson County	Acquisition grants	2.0	1.0	1.0	1.0	1.0
Multnomah County	Acquisition grants	2.0	5.0	1.0	1.0	1.0
City of Orange	Garage retrofit	2.0	1.0	1.0	1.0	1.0
	Yard retrofit	2.0	1.0	1.0	2.0	1.0
	Pump station retrofit	2.0	1.0	1.0	2.0 (water benefits only; resulting 1.72 overall)	1.0
Tuscola County	Acquisitions	2.0	1.0	1.0	1.0	1.0
	Moore Drain structural mitigation	2.0	1.0	1.0	1.0	1.0

For Freeport, frequency of flooding is the dominant variable in the high benefit-cost ratios. For lower bound estimates, several key assumptions were made to decrease the exposure of structures (elevating streets by a multiplier of two, elevations by a multiplier of five) and to limit future repair costs (reducing clean-up costs by a multiplier of 2.8 because of water-proofing as a result of prior floods). Inasmuch as models used did not capture all the flooding, no lower bound adjustments were made for estimates of frequency of occurrence of flooding. For upper bound estimates, clean-up costs were increased by a factor of 1.43 for building elevation projects and the exposure was doubled for street elevating projects. The results show that in the extreme lower case, the benefit-cost ratio can be lower than one. In the extreme upper-case, the benefit-cost ratio can be close to four times higher than the mean value. As discussed in the paragraph above, these extreme estimates included variation of discount rates and hazard level frequencies (here, only in the upper bound case).

The benefit-cost ratios for Hayward are high. The most significant hazard for this community is earthquake. Largely because of the high indirect benefits associated with the continued functionality of the fire stations and the potential for a large number of casualties should chlorine be released from wastewater facility, the benefit-cost ratio for the community exceeds seven. Even varying the assumptions for the wastewater facility (e.g., including future maintenance costs) and increasing the discount rate to 7 percent still results in benefit-cost ratios greater than one. Note that the high marginal increased maintenance costs at the sodium hypochlorite facility

influence the impact of the use of a 7 percent as opposed to a 2 percent discount rate. Maintenance costs are lower if the discount rate is higher.

The average benefit-cost ratios for all activities in Horry County are above one despite the fact that many of the individual properties within the overall project to buy-out properties for flood (about 30 percent) were less than one. Uncertainties evaluated pertain only to shutter retrofits, buyouts, and elevations. Both discount rate uncertainties and uncertainties in frequencies of occurrence yield a lower bound benefit-cost ratio below one.

In Jamestown, the benefit-cost ratio for the Oxbow dike is lower than one because there are few residences with basements that would be protected from flooding by the mitigation measure. As indicated previously, the expected cost to repair flooded basements was obtained from Nelson (oral communication, Oren Nelson, 2005). In the case of the lift station, more individual residences would benefit from the upgrade of this facility and, thus, the benefit-cost ratio is greater than one. The community benefit-cost ratio is greater than 1.0. Downside uncertainties cover all five types of estimates and could yield an overall estimate less than 1.0. These downside estimates include a reduction in the number of flooded basements by a factor of two and a reduction in clean-up costs by a factor of 2.8. Upside estimates increase the number of structures exposed by a factor of two and take into account possible increases in clean-up costs in the Oxbow area and a possible doubling of the life span of the mitigations. Upside uncertainties indicate that the extreme range of benefit-cost estimates is very high.

For Jefferson County, where all the mitigation projects were flood buy-outs, the benefit-cost ratio is above one, even though a number of the individual purchases had benefit-cost ratios less than one. The extreme range of benefit-cost ratios depends only on uncertainties in frequency of occurrence and discount rate selected.

In Multnomah County, the hazard being mitigated is debris flow. The best estimate of the benefit-cost ratio is above one. Yet, this value is highly dependent on the assumptions made with regard to number of reduced casualties. On the downside, estimates of rates of casualties are reduced by a factor of two along with dividing the frequency of occurrence by a factor of two and using a 7 percent discount rate. On the upside, estimates of rates of casualties are multiplied by a factor of five along with increasing the frequency of occurrence by a factor of two. By varying this assumption, the benefit-cost ratio can be as low as 0.13 or as high as 11.7. The extreme range exhibits how little is known about estimating benefits of buyouts in locales prone to debris flows.

In the City of Orange, the overall best estimate of the benefit-cost ratio for earthquake mitigation activities is two. The benefit-cost ratio for the complete seismic retrofit of a critical water pump station is low because a full-scale water system evaluation was not performed; only (conservative) proxy estimates of systemic consequences of pump station failure were included. Twenty percent of the water supply was assumed to be lost during the downtime of this facility with its four wells and associated pumps. Note that these wells can produce up to 80 percent of the water supply for the City of Orange. A much more comprehensive systems evaluation would be required to account for the apparent redundancies in the City of Orange potable water system (oral communication plus calculations, Robert Baehner, P.E., City of Orange Water Department, 2005). To estimate the downside uncertainties in the City of Orange estimates, estimates of the exposed population in the city yard are divided by two along with normal reductions in estimates

of the frequency of hazard occurrence and resulting impacts of using a 7 percent discount rate. Estimates of upside estimates considers doubling the benefits of the pump station retrofit and doubling the exposed population in the city yard as well as doubling the frequency of occurrence of the hazard. Varying these assumptions yields an extreme range of benefit-cost ratios from 0.4 to 5.0.

In Tuscola County, flooding is frequent and reaches high levels, thus causing serious damage at 5- and 10-year recurrence intervals. Because of this high frequency of damaging floods, the average benefit-cost ratio is over 12. In the sensitivity analysis, downside estimates considered a 7 percent discount rate and a reduced exposure for the Moore Drain structural mitigation of 50 percent. Owing to the high frequency of flooding (and the fact that the two-year flood was not analyzed), no downside uncertainties were estimated for frequency of occurrence of flooding. On the upside, only the frequency of occurrence was considered. Note that including of factors such as adjusting for such additional factors as reduced trip delays, emergency care benefits, and benefits of advance warning could yield even higher benefits. Even without these additional possible benefits, the range of benefit-cost ratios is from 2.8 to 24.9.

5.4.2 Project Impact Grants

Project Impact grant expenditures are generally small relative to other types of FEMA grants. Furthermore, in many cases, it is extremely difficult to calculate the benefits associated with these types of grants, largely because of their unique nature. Some of the more common mitigation projects include community warning systems, education activities, and purchase of special equipment or hardware. In many cases, Project Impact grants were used for multihazard mitigation process and small project activities. Each community began its mitigation efforts by creating a coalition to support grass roots engagement in mitigation.

Table 5-17 presents, for each community, the types of mitigation activities funded, the costs of these activities (including FEMA's share), estimates of the total benefits, estimates of the benefit-cost ratios, and ranges of benefit-cost ratios. Tables 5-18 and 5-19 clarify how the ranges of benefit-cost ratios are derived. As with similar evaluations for HMGP grants, the uncertainty evaluations consider impacts of uncertainties in the following estimates:

1. Frequency of occurrence of the hazard,

2. Casualty rates/costs,

3. Discount rate impacts,

4. Exposure, and

5. Clean-up costs.

Table 5-17 Summary of costs, benefits, benefit-cost ratios and ranges by Project Impact activity and community

Community	Brief Description of Mitigation Activity	Total Costs including Annual Maintenance (2002 $M)	FEMA Costs (2002 $M)	Best Estimate		
				Benefits (2002 $M)	Benefit-Cost Ratio	BCR Range
Freeport	Community early warning system	0.44	0.02	7.86	17.9	1.8 – 71
	Education	0.13	0.10	Not calculated	Not calculated	Not calculated
	Hurricane shutters	0.03	0.02	0.01	0.3	0.15 – 0.6
	Tree removal	0.02	0.02	Not calculated	Not calculated	Not calculated
	Freeport Totals	*0.63*	*0.16*	*7.87*	*12.6*	*1.3 – 50*
Horry County	Warning systems	≤0.13	0.04	0.16	1.20	1.20
	Fire hydrant reflectors	≤0.04	0.02	0.05	1.20	1.20
	Education activities	≤0.04	0.03	Not calculated	Not calculated	Not calculated
	Horry County Totals	*0.16 (limits of governmental funds)*	*0.12*	*0.21*	*1.28*	Not calculated
Jamestown	Civic center as safe room, warning for safe rooms	0.12	.10	0.24	1.96	0.2 – 6.07
	Other activities	0.19	1.44	0.18	0.93	0.28 – 0.93
	Jamestown Totals	*0.31*	*0.24*	*0.42*	*1.33*	*0.28 – 2.92*
Jefferson County	Community early warning and emergency information systems	0.12	0.09	0.40	3.45	0.85 – 10.5
	Other activities including Edgewater Oaks safe rooms	0.19	0.14	0.42	2.2	0.55 – 6.8
	Jefferson County Totals	*0.31*	*0.24*	*0.82*	*2.6*	*0.67 – 8.3*
Multnomah County	Emergency kits and model home	0.15	0.11	0.08	0.53	0.2 – 0.6

Table 5-18 Upside factors used in uncertainty calculations for Table 5-17

Community	Brief Description of Mitigation Activity	Frequency of Occurrence	Casualty Rates / Costs	Discount Rate Impact	Exposure	Clean-up Costs
Freeport	Community early warning system	2.0	1.0	1.0	1.0	2.0
	Hurricane shutters	2.0	1.0	1.0	1.0	1.0
Jamestown	Civic center as safe room, warning for safe rooms	2.0	1.55	1.0	1.0	1.0
Jefferson County	Community early warning and emergency information systems	2.0	1.55	1.0	1.0	1.0
	Other activities including Edgewater Oaks safe rooms	2.0	1.55	1.0	1.0	1.0
Multnomah County	Emergency kits and model home	1.0	1.0	1.0	1.13 (incomplete data on activities undertaken)	1.0

Table 5-19 Downside factors used in uncertainty calculations for Table 5-17

Community	Brief Description of Mitigation Activity	Frequency of Occurrence	Casualty Rates / Costs	Discount Rate Impact	Exposure
Freeport	Community early warning system	0.5	1.0	1.0	0.2
	Hurricane shutters	0.5	1.0	1.0	1.0
Jamestown	Civic center as safe room, warning for safe rooms	0.5	1.0	1.0	0.2
	Other activities	1.0	1.0	1.0	0.3 (incomplete data on activities undertaken)
Jefferson County	Community early warning and emergency information systems	0.5	1.0	1.0	0.5
	Other activities including Edgewater Oaks safe rooms	0.5	1.0	1.0	0.5
Multnomah County	Emergency kits and model home	1.0	1.0	1.0	0.38 (incomplete data on activities undertaken)

Uncertainty ranges are not evaluated for those activities whose best estimate is derived through use of the benefit transfer method. As with similar uncertainty evaluations for HMGP grants, the function of uncertainty evaluations is to expose the extreme range of possible estimates rather than to demonstrate the robustness of the evaluation. Benefit-cost evaluations for natural hazard risk reduction activities generally contain inherent uncertainties in the estimation of frequencies of occurrence of the natural hazard and potential uncertainties in policy-level determinations of a discount rate. Practical uncertainties also arise to the extent that the costs of gathering additional information to reduce some uncertainties become prohibitive relative to the gains.

For Freeport, the dominant activity was the development of warning systems that permit Freeport residents to use sandbags to avoid damages especially to appliances and other items found in lower stories. Warning systems were assumed to permit 500 residences to use sandbags every two years, with a savings of $1000 per residence per event. Uncertainties on the downside consider a reduced exposure of 100 residences and a frequency of occurrence that is halved. Discount rate impacts do not exist because casualty estimates were not discounted. On the upside, clean-up costs are doubled as is the frequency of occurrence of the flooding. HAZUS®MH was used to evaluate the benefits of hurricane shutters. Benefits from other activities were not estimated. Overall, given the efficacy of sandbagging, the basic benefit-cost ratio is above 12, and the extreme range of benefit-cost ratios ranges from 1.3 to 50.

For Horry County, benefit transfer estimates from the benefit-cost analysis of FEMA mitigation grants methodology were used to provide benefit estimates for two of the major activities: warning systems and fire hydrant reflectors. Some of the funding of these activities came through donations. The overall benefit-cost ratio considers only government funding, whether local or federal. No range of benefit-cost ratios is estimated.

For Jamestown, the tornado model developed in this project was used to estimate benefits of the community early warning system (Section 4.3.2). It was assumed that up to 3000 people could

use the civic center as a safe room during tornado events. Based on the field investigation, the civic center can easily hold 3000 people and shelter time for tornado warnings tends to be relatively brief in the experience of the project investigators. No travel time evaluation was performed to determine whether or not parties could reach the shelter in sufficient time before the tornado arrived. Downside estimates reflect this uncertainty through a reduction of the exposed population by a factor of five as well a frequency of occurrence that is doubled. No discount rate is applied to casualties. For other activities in Jamestown, the benefit transfer methods are uncertain on the downside only to the extent that field documents did not fully clarify that all proposed activities were undertaken.

The Jefferson County Project Impact grant had a spin-off, the Edgewater Oaks residential development with safe-rooms. For this spin-off, it was assumed that safe rooms had private costs of $3000 each, that there were 80 such safe rooms constructed, and that the estimated gross casualty benefit was $8087 for each safe room. Downside uncertainties included a reduction of people exposed by 50 percent along with doubling the frequency of occurrence. Upside uncertainties included uncertainties in the casualty costs in the tornado model as well as dividing the frequency of occurrence by a factor of two. The early warning system connected with the Jefferson County Project Impact grant applies to flash floods, severe weather, and tornadoes. Only tornado warnings were evaluated. These assumed conservatively that 100 people received tornado warnings and moved to safe shelters. The net benefit per person was $4,043, as calculated by the tornado model. The downside uncertainty range included a reduction in people exposed and a doubling of the frequency of tornado occurrence. Upside uncertainties included a reduction in the frequency of occurrence along with an increase in casualty cost estimates. Omitted from the calculations were additional advantages of flash flood and other warnings.

The Multnomah County Project Impact grant suffered from an administrative change that led to the discontinuation of many of the activities started or only planned. Of the $150,000 allocated, $30,000 was used for a school project to develop an advanced version of a perennial 72-hour emergency kit program. Another $50,000 may be credited to the retrofitting of an older flood prone house to train homeowners and contractors on alternative seismic and other retrofitting approaches. Based on a benefit transfer benefit-cost ratio of 1.0 for these two activities, the overall benefit-cost ratio was 80/150, or 0.53. Uncertainties primarily pertained to limitations in the field investigations pertaining to the extent to which these activities were undertaken. No evaluations were performed of the $150,000 transferred to the City of Portland, for which additional investigations might find significant benefits.

5.4.3 Spin-Off Activities Resulting from HMGP Grants

As described in the discussion of Jamestown in Section 5.2.4, the design of the storm water runoff system for the new high school can be linked to the Project Impact grant. One activity in Project Impact was to complete a community storm water run off study; after its completion, the new high school in Jamestown was designed using this study. In the case of other spin-off activities, there was no cost that could be considered apart from the costs of HMGP grants. To develop benefit-cost ratios for these spin-offs would have counted the costs twice. Hence, benefit-cost ratios could not be developed for several spin-off activities. These spin-off activities are summarized in Table 5-20.

Table 5-20 Net benefits for spin-off activities not covered in Table 5-17

Community	Mitigation Descriptor	Costs Not Borne by or Required by FEMA (2002$M)	Net Benefit treated as an acceleration (2002$M)	Net Spin-Off Benefit not treated as an acceleration (2002$M)
Hayward	Tilt-ups	42.9	7.6	213.6
	URMs	10.8	1.3	49.2
	TOTALS	*53.7*	*8.9*	*262.8*
Horry County	Code development	36		3.6
Tuscola County	A few residences elevated more than required	Low	Low	Low
	Residential development grading	Low to medium	Low to medium	Low to medium

For Hayward, there was strong, but not indisputable evidence that the seismic retrofit ordinances for tilt-ups and unreinforced masonry retrofits would not have occurred had FEMA not provided Hazard Mitigation Grant Program funding. Still, for the sake of conservatism, it was also assumed that adoption of these ordinances may only have been accelerated by ten years. Because this evaluation did not apply a discount rate to casualties, no casualty benefit reduction could be calculated for the assumption of acceleration. Only property benefits were calculated given the assumption of acceleration. Thus, the assumption of acceleration yielded much lower net benefits than the assumption that the tilt-up seismic and unreinforced masonry retrofits would not have taken place at all in the absence of Hazard Mitigation Grant Program funding.

The Horry County spin-offs are speculative. Evidence exists that the Clemson University study, which used purchased buildings for destructive testing, will result in improved national model building codes and that these will affect the very rapid residential development in Horry County. A benefit-cost ratio of 1.1 was used to estimate these based on benefit-transfer methods. Marginal wind-resistance costs were assumed to be about 0.4 percent of the dwelling replacement cost. Based on field data, it is expected that 10,000 new residences (or roughly $1 billion in residential construction costs in 2002 dollars) will be built in Horry County per year over the next 10 years. When these marginal wind-resistance costs are annualized, these amount to about four million dollars. Over a ten-year period at a 2 percent discount rate, these private marginal wind-resistance costs are about $36 million. Net benefits are similarly estimated to be $3.6M. Uncertainties depend on the fact that this study may result in no code improvements, on the lower bound side. On the upper bound side, benefit-transfer methods used assumed a very low benefit per new residence based on these code improvements. Moreover, hearsay evidence (not found in the field investigations) suggests that these Clemson studies are producing benefits in other jurisdictions, including other states. Thus, future investigations may yield very significant spin-off benefits for these spin-offs resulting from the Clemson studies.

Other spin-off benefits, such as those in Tuscola County, were only generally estimated based on other calculations made for flooding impacts on residences in the Village of Vassar.

5.4.4 Cost-Effectiveness Analysis of Grants for Process Mitigation Activities

Data and methods are largely lacking for quantifying benefits for process mitigation activities. Instead of cost-benefit analysis, therefore, a cost-effectiveness approach was used. Cost-effectiveness analysis is a commonly used alternative to cost-benefit analysis in situations where the inability to monetize benefits prevents the implementation of cost-benefit analysis. In cost-effectiveness analysis, alternative actions are compared on the basis of their costs and a single quantified measure of effectiveness (Boardman et al., 2001).

The approach here involved using the telephone interview data to compare the effectiveness of process mitigation activities with the effectiveness of comparable project mitigation activities for which quantitative results were available on benefit-cost ratios. Comparability was determined from interview data on mitigation objectives. Note that the costs of process mitigation activities are typically much less than those of comparable project mitigation activities. Consequently, if a process mitigation activity is found to be at least as effective as a comparable project mitigation activity and if this project mitigation activity has a benefit-cost ratio greater than one, it can be inferred that the process mitigation activity is cost-effective. Results consisted of binary ratings for each community indicating whether or not it had invested in cost-effective process mitigation activities. The telephone interview database identifies four "process" mitigation activities in the NEMIS database, seven Project Impact mitigation cases (some of which included process mitigation activities), eleven spin-off mitigation activities (some of which included process mitigation activities), and one "other process" mitigation activity. One community, Jamestown, did not have any process mitigation activities in the telephone interview database.

The following procedure is used to determine the value of the cost-effectiveness variable for each community. Using the telephone interview database, process mitigation activities were identified for each community. For each process mitigation activity, it was then determined whether there were other project mitigation activities in that community that have a similar major objective and for which quantitative benefit-cost ratios are calculated in the current study. These project mitigation activities were compared to the process mitigation in terms of respondents' perceptions of their effectiveness. Specifically, data were used from the respondents' assessments, on a scale of 1 to 10, of "the community's success in meeting this objective" both with and without the specific mitigations. Finally, this relative effectiveness was considered in light of the available benefit-cost ratios. For example, if a process mitigation activity is more effective at achieving a certain objective than a project mitigation activity with a similar objective (e.g., safety) and the project mitigation activity had a high benefit-cost ratio, the process mitigation activity is regarded as being cost-effective.

Only information from respondents who are at least moderately familiar with the mitigation activity was considered in the cost-effectiveness analysis. Respondents' assessments of mitigation effectiveness are weighted by their degree of familiarity with the mitigation. Respondents indicated their familiarity on a scale of 1, "not at all familiar" to 10, "extremely familiar." The following weights were applied: for respondents with a familiarity level of 9 or 10, a weight of 1.0; for a familiarity level of 7 or 8, a weight of 0.75; for a familiarity level of 5 or 6, a weight of 0.5; and for a familiarity level of 1 to 4, a weight of 0. Information on spin-off activities created by the mitigation also was considered. Table 5-21 summarizes the resulting

cost-effectiveness estimates. This table does not include process mitigation activities that could not be evaluated by the procedure described above due to insufficient data.

Table 5-21 Cost-effectiveness estimates for process activities

Community	Process Mitigation Activities in Analysis	Cost-Effective
Freeport	Project Impact (warning system)	Yes
Hayward	Public awareness and education	No
Horry County	Local beach management plan	Yes
Jamestown	None identified	No
Jefferson County	Project Impact (warning system)	Yes
Multnomah County	Project Impact (emergency kits)	No
Orange	Feasibility studies for retrofits	Yes
Tuscola County	Feasibility study of Moore Drain	Yes

5.5 Nonquantifiable Benefits

In benefit-cost and cost-effectiveness analyses, benefits are defined as avoided losses and do not include such positive benefits as community awareness and peace of mind. In this study, no estimates were made to quantify the value of knowledge in the general population of hazard risks, preparedness activities, recovery activities, or other emergency management topics that were the foci of educational programs. Also no estimates were made of the distribution of acceptable risk made by citizens that might be used to determine the percentage of the population who might have incorporated mitigation activities to limit their future losses and gain peace of mind. Interviewees in the communities, however, did indicate risk averse citizens invested in mitigation activities, i.e., saferooms, window shutters, preparedness kits, electric generators, or plywood for boarding.

Communities also benefited from open discussions of community plans and educational programs. When opposition existed, advocates or champions had to strengthen their positions and improve their products, leading to plans and programs that were more attuned to community wishes and likely increased the buy-in of citizens to make these programs successful.

Changes in the community esprit de'corps because of mitigation projects were not quantified. Again, anecdotal evidence indicated that highly visible mitigation programs (i.e., street elevations, storm water management facility improvements, and physical improvements to flood control works) improved the community image, which inspired residents to improve their homes and infrastructure. These results were very evident in Tuscola and Freeport where redevelopment took place in historic commercial centers. Coincident with redevelopment were increased demand for homes, higher home prices, home improvements, and infrastructure improvements to parks and other community meeting places.

Finally, it should be noted that the value of synergistic activities calculated using benefit-cost analysis does not accurately portray the value to the communities. Several synergistic activities (e.g., downtown redevelopment, preservation of an historic district, and related efforts to

increase community revenues) were matters of extreme local significance but are insignificant on a national scale. Increased business in the Village of Vassar will, for instance, not have significant impacts regionally inasmuch as these businesses could have located in nearby communities. Likewise, increased city revenues resulting both from increased businesses and not having further residents and businesses leave this small community mean a great deal to those in this small city, but little regionally or nationally from a standard economic viewpoint.

5.6 Comprehensiveness Factor

The results of the community studies provide valuable insight into how synergistic effects (i.e., spin-off effects) may result from FEMA expenditures. As discussed earlier, collateral effects are not regarded in this study as resulting from FEMA expenditures. Spin-off effects are already included in the estimation of direct benefits of HMGP grants.

The comprehensiveness factor indicates the additional benefits, relative to the total cost of the grant — original FEMA and matching costs — that may be estimated from spin-off activities and effects. Spin-off benefits do not overlap with any specific benefits associated with the grant itself (e.g., risk reductions that take place in accordance with the grant itself). The comprehensiveness factor is not a benefit-cost ratio factor.

Table 5-22 provides basic information how on the comprehensiveness factor was estimated in this study. Table 5-22 begins with a statement of FEMA costs. These costs may be derived based solely on HMGP costs. In this case, derived spin-off benefits result only from HMGP grants. Alternatively, these costs may be derived based on the combined costs of HMGP and Project Impact grants. In this case, spin-off benefits are derived from both types of grants. These alternative accounts of the comprehensiveness factor (i.e., based on HMGP grant costs only, or on both HMGP and Project Impact grant costs) provide an indication of the sensitivity of this factor on two different assumptions regarding total cost.

Table 5-22 Basic estimates used in deriving a comprehensiveness factor

Community	Total HMGP Costs ($M)	Total Project Impact Costs ($M)	Project Impact Spin-off Benefits (best estimate; $M)	Spin-off Benefits from HMGP Grants (high estimate; $M)	Spin-off Benefits from HMGP Grants (low estimate; $M)
Freeport	5.11	0.626	0	0	0
Hayward	6.95	0	0	213.6	8.9
Horry	7.45	0.160	0	3.6	0.009
Jamestown	0.65	0.315	0	0	0
Jefferson	3.17	0.314	0.403	0	0
Multnomah	0.91	0.150	0	0	0
Orange	0.86	0	0	0	0
Tuscola	2.52	0	0	0.100	0.100
TOTALS	$27.62	$1.565	$0.403	$217.3	$9.0

In the case of Hayward, because it can be argued whether or not the spin-off activities were a direct result of or were only accelerated by the FEMA mitigation grants, alternative estimates were developed both for the lower estimate (on the assumption that these activities were merely accelerated) and for the higher estimate (on the assumption that these activities would not have occurred without the FEMA grant).

Based on Table 5-22, one can derive the following low and high estimates for this comprehensiveness factor:

   0.324 as the low estimate relative to total costs [weighting equally 0.326, or 9000/27,618 for HMGP grants only and 0.322, or (9000+403)/(27618+1564.7) for HMGP and Project Impact grants]

   7.78 as the high estimate relative to total costs [7.87, or 217,300/27,618, for HMGP grants only and 7.46, or (217,300+403)/(27,168 + 1564.7) for HMGP and Project Impact grants]

The variations between low and high estimates demonstrate how much the comprehensiveness factor depends on whether or not one treats the Hayward spin-offs as being accelerated. The sensitivity of these results further demonstrates how skewed the distribution is from the synergistic benefits estimated in the limited community studies.

The variations between using HMGP grants only and using both HMGP and Project Impact grants are very small, but nonetheless arise because Jefferson County spin-offs result from the Project Impact grant. Hence, if this spin-off is included in the development of the comprehensiveness factor, then all Project Impact costs should be included. Other Project Impact benefits are not included because they are not spin-off benefits.

For this study, it is assumed that that the Hayward spin-offs should be treated as being accelerated. Thus, for each dollar spent by FEMA and the local government (in cost-sharing), the synergistic benefits are estimated to be $0.32.

5.7 Summary

In each of the eight communities studied, federal hazard mitigation grants, including Project Impact, were a significant part of the community's mitigation history. As shown in the eight activity chronologies (Figures 5-1 through 5-8), the federal hazard mitigation grants often led to additional or synergistic activities. Interviewees in all communities, as reported in Section 5.1.2, thought the grants were important in reducing community risks, preventing future damages, and increasing a community's capacity to mitigate natural hazards. Most believed the grants permitted their communities to achieve mitigation goals that might not otherwise have been reached.

Overall benefit cost ratios were over one in all eight communities without including additional calculations for activities such as public education. While some individual projects had benefit cost ratios less than one, for the most part, communities undertook cost beneficial projects. Interviewees in each community believed that benefits of the mitigation projects went beyond what could actually be measured quantitatively. These included increased community

awareness, esprit de corps, and peace of mind. Virtually every interviewee believed that their community was better off after mitigation project and process activities were completed.

Chapter 6
BENEFIT-COST ANALYSIS OF FEMA MITIGATION GRANTS

The results of the benefit-cost analysis of FEMA mitigation grants are presented and explained below. These results are based on the data and methods summarized in Chapters 3 and 4. Results are presented for two major categories of grants ─ those for project activities and those for process activities; and for three hazards ─ earthquake, flood, and wind.[62] Classification thus resulted in six strata. Specific methods and data used in the estimation of each stratum are also identified.

Because this was a statistical analysis, the emphasis was placed on major statistical indicators applicable to an entire stratum the mean benefit and its standard deviation ─ rather than on individual grants. Explanations are offered for statistical outliers (extreme values) and for those cases where the results are unusual or counterintuitive.

Overall, the benefit-cost analysis of FEMA mitigation grants found that the benefit-cost ratio of all strata were greater than 1.0. Moreover, this result is robust to formal sensitivity tests and informal evaluations of methodological limitations and assumptions.

The sample results also were extrapolated to the population totals. The total national benefits of FEMA hazard mitigation grants between mid-1993 and mid-2003 are $14.0 billion compared with $3.5 billion in costs. This yielded an overall benefit-cost ratio of 4.0. This means that the benefits of these grants to the nation significantly exceed their costs.

In addition, the savings to the federal treasury were estimated. Federal expenditures on hazard mitigation were juxtaposed against potential savings in federal post-disaster recovery expenditures and recouped federal taxes. The results were that every dollar of hazard mitigation expenditures potentially saves the federal treasury $3.65 of future discounted expenditures or lost taxes. Thus, in addition to providing broad-based benefits to society, the FEMA hazard mitigation grant programs more than pay for themselves.

6.1 Project Selection

This study addresses all FEMA-funded mitigation grants that satisfy the following criteria: (1) the grant was listed in the NEMIS database provided by FEMA in July, 2003; (2) the grant was associated with presidentially declared disaster number 993 (Midwest floods of June 1993) or later; and (3) the grant was intended to reduce future losses associated with earthquake, flood, or wind (including both hurricanes and tornadoes) as determined using FEMA's coding for project type. Where the project-type code did not reveal the hazard to be mitigated, the hazard was assumed to be the same as that of the declared disaster, and this assumption was cross-checked by a review of the grant application.

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[62] The results for a third category of grants, Project Impact grants, are presented in Chapter 5.

6.2 Stratified Sample

Project data were acquired in electronic format for 5,479 approved or completed grants to mitigate flood, earthquake, or wind risk. The data were stratified by hazard type (flood, earthquake, or wind) and mitigation type (project or process activity). A selection of 357 mitigation grants was made for examination. Each combination of mitigation type (project or process) and hazard represents one stratum. The study investigators collected additional data on as many of these grants as possible (see Section 3.2.2 for discussion of this process).

A rigorous random sampling technique was applied to select these 357 grants (see Section 4.5.1 for details). The sample grants were selected to represent the distribution of mitigation costs and to ensure the inclusion of low, medium, and high-cost mitigation efforts in each stratum. FEMA was able to provide paper copies of 312 grant applications. Data were extracted from these paper files and transcribed to electronic coding forms in a detailed and structured fashion. The form for project mitigation activities contained 200 data fields for each property or location mentioned in the grant application. Eventually, 54,000 data items were extracted for the stratified sample, consisting of 1,546 properties in project mitigation activities and 387 distinct efforts in process-type activities. Many of the 312 grant application files contained insufficient data to estimate benefits of mitigation, and a few produced results that caused investigators to exclude them from the final sample (these "outliers" are discussed later). Eventually, 136 grant applications remained in the sample.

Table 6-1 summarizes the distribution of these grants by mitigation type and hazard for the entire population of grants that satisfy the criteria listed in Section 6.1 and for the sample that was selected to represent the population. The table distinguishes grants that involve the actual mitigation of risk (project mitigation activities such as structural retrofit) from activities involving support functions (process mitigation activities such as public awareness campaigns or research).

Table 6-1 Distribution of grants by mitigation type and hazard (in 2004 dollars)

		Population		Sample	
Hazard	**Type**	**Count**	**Cost ($M)**	**Count**	**Cost ($M)**
Wind	Project	1,190	280	42	38
	Process	382	94	21	38
Flood	Project	3,404	2,204	22	84
	Process	108	13	6	2
Earthquake	Project	347	867	25	336
	Process	48	80	20	74
Total		5,479	$3,538	136	$572

6.3 Sample Results

6.3.1 Sampled Grants for Project Mitigation Activities

This section covers grants for project mitigation activities only for earthquake, wind, and flood. Section 6.3.2 discusses the sampled grants for process mitigation activities for these hazards.

The results of the benefit-cost analysis of FEMA project grants are discussed below. Although some details are presented at the individual grant level, the benefit calculations and the benefit-cost ratio results are valid only at the aggregate level. This is consistent with the general nature of statistical studies of this kind. The benefit-cost ratios calculated in this part of the study were independent of those provided in grant applications. There were several reasons for this, including the need to develop and implement an independent methodology for estimating future benefits, and the fact that the focus of this study was on aggregate benefits and not on the benefits of individual grants.

A list of methods used to measure each benefit type for each hazard is presented in Table 6-2. Table 6-2 also includes the section of this report in which a detailed explanation of the method is found.

6.3.1.1 Grants for Earthquake Project Mitigation Activities

The earthquake stratum of grants for project mitigation activities includes grants for both structural activities (e.g., base isolation of public buildings) and nonstructural activities (e.g., retrofit of pendant lighting in schools). Overall, the stratum sample included 25 grants involving 128 buildings. Pendant lighting projects in schools accounted for the majority of the buildings analyzed in this stratum, with one grant addressing the replacement or mitigation of seismically vulnerable light fixtures in 78 sample buildings. Higher cost grants included seismic upgrades and seismic safety corrections of hospitals, university buildings, and other public buildings.

HAZUS®MH was the primary methodology used in estimating property damage, direct and indirect business interruption losses, and some societal impacts such as casualties. It was applied using structural, economic, and societal information and data obtained from grant applications found in FEMA files, and supplemented with published data on some key projects.

New methods were developed for estimating some types of avoided losses (see discussion in Section 4.3). These avoided losses included business interruption impacts associated with utility outages, damage to pendant lighting and ceilings, environmental/historical benefits and some societal benefits (see Appendices C through K). Section 2.1.1 discusses the fact that independent estimates of the costs of administering FEMA grants could not be obtained.

The simple average benefit-cost ratio for the 25 grants in this stratum is 1.4, with a standard deviation of 1.3. The total benefit for this stratum is $1.2 billion. Individual grant benefit-cost ratios range from near zero for a nonstructural retrofit to an electricity substation (intended to reduce physical injury to workers) to 3.9 for a nonstructural retrofit of a hospital.

Table 6-2 Methods used to estimate benefits for grants for project mitigation activities[1]

Benefit Type	Earthquake	Wind		Flood
		Hurricane	Tornado	
Property Damage	HAZUS®MH (Section 4.2.1)	HAZUS®MH (Section 4.2.1)	HAZUS®MH Reduced Form (Appendix H)	HAZUS®MH Reduced Form (Appendix G)
Business Interruption				
Utilities	HAZUS®MH Extension[2] (Appendix I)	HAZUS®MH Extension[2] (Appendix I)	HAZUS®MH Extension[2] (Appendix I)	n.a.[3]
Other	HAZUS®MH (Sec 4.2.2, 4.2.3)	HAZUS®MH (Sec 4.2.2, 4.2.3)	HAZUS®MH (Sec 4.2.2, 4.2.3)	n.a.[3]
Displacement	HAZUS®MH[4] (Sec 4.2.2)	HAZUS®MH[4] (Sec 4.2.2)	HAZUS®MH Extension[2,4] (Sec 4.2.2)	HAZUS®MH Extension[2] (Sec 4.2.3.3)
Casualty[5]				
Structural	HAZUS®MH (Appendix E)	Benefit Transfer (Appendix E)	HAZUS®MH Reduced Form[6] (Appendix E)	Benefit Transfer (Appendix E)
Nonstructural	Benefit Transfer (Appendix E)	n.a.[7]	n.a.[7]	n.a.[7]
Environmental and Historical	Benefit Transfer (Sec 4.3.4; Appendix J)	Benefit Transfer (Sec 4.3.4; Appendix J)	Benefit Transfer (Sec 4.3.4; Appendix J)	Benefit Transfer (Sec 4.3.4; Appendix J)

[1]A "surrogate benefit" method was used to estimate all benefit categories for process activities (Section 4.3.5 and Appendix K).

[2]Extension refers to a method that builds on HAZUS®MH with a similar and compatible approach.

[3]None of the sampled flood projects involved business interruption.

[4]Measured as part of business interruption.

[5]Also includes emergency services benefits.

[6]Reduced Form refers to the use of component parts, such as functional relationships and data, from a HAZUS®MH module.

[7]Only relevant to earthquakes.

HAZUS®MH was used to estimate property damage avoidance (benefits) due to the structural upgrades. These benefits can be significant, with property loss reductions measuring between a few percent and 3.9 times the cost of the retrofit. The total property loss reduction for this stratum is $319 million. Property loss reduction alone, however, was not sufficient for the average benefit-cost ratio from mitigation measures in this stratum to exceed 1.0. Of the 25 hazard mitigation grants in the earthquake project stratum, three avoided business interruption. The cases where business interruption was applicable included impacts on utilities and hospitals; no conventional business activities other than these were in the sample. (This estimation here and for other hazards excludes public buildings such as police and fire departments, civic arenas,

and schools.[63]) In addition, an inherent assumption of the HAZUS®MH methodology is that only structural mitigation results in business interruption benefits.[64] The vast majority of nonstructural mitigation measures in this stratum are for pendant lighting in schools, and is assumed only to affect casualty rates.

For the three applicable cases in the earthquake project grant sample stratum, business interruption benefits average $52.9 million, and range from a low of $1.3 million for a pump station to a high of $139.5 million for a hospital. Business interruption benefits contribute about 10 percent to the overall average benefit-cost ratio for this stratum.

The largest component of benefits in the earthquake project stratum was the reduction of casualties, which accounted for 62 percent of the total benefits. Analysis shows that a reduction of about 542 injuries and 26 deaths in this stratum is expected, which translates into $131.3 million. The mean benefit per grant is about $6.3 million, with a standard deviation of $6.4 million. The projects with zero calculated casualty benefits included electrical substation upgrades, a school arcade replacement, and nonstructural mitigation activities to emergency power and communication facilities (rather than patient services) in a hospital.

Three earthquake grants provided environmental or historical benefits, including improving water quality, protecting historic buildings, and positive health benefits. The highest environmental benefit was for an earthquake retrofitting of a police headquarters building ($293,000), while the lowest pertains to health benefits of a hospital retrofit. The average benefit of these three grants is nearly $143,000, and they accounted for less than 1 percent of the total benefits in the earthquake project grant stratum.

No significant outliers exist in the earthquake project stratum, with the exception of two nonstructural mitigation grants. These two grants did not provide much property protection, almost no casualty reduction, and no protection at all against business interruption.[65]

For this stratum (as well as for the others below), the overall approach has leaned toward conservatism. In this stratum, estimates of the diffusion of university research and of demonstration projects, as well as several types of societal impacts related to psychological trauma, were omitted because there was no adequate means of quantifying these measures. Also omitted in this and other strata were: indirect property damage (e.g., prevention of ancillary fires), avoided negative societal impacts relating to psychological trauma (e.g., crime, divorce), air quality benefits (improvements in visibility and health due to reduced burning debris), benefits from reduced disposal of debris (land quality), and aesthetic benefits including visibility and odors of reduced debris.

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[63] These public sector activities, although not priced as a business product or service, do yield commensurate value even if usually not transacted through the market. However, they have been omitted from business interruption calculations because, in the aftermath of a natural disaster, most of their functions are provided by other locations or "recaptured" at a later date. Moreover, payments for major inputs continue even when the original facility is closed (e.g., wages to unionized employees).

[64] For the earthquake and wind project strata, business interruption also included the costs of displacement effects. For the case of buyouts of flood-prone residences, these effects were calculated separately.

[65] Those projects with low benefit-cost ratios include some cases of nonstructural mitigation intended primarily for life safety. Other cases of this same type of mitigation yield some of the higher benefit-cost ratios, along with structural retrofit of large buildings. The seeming incongruity of the benefits of nonstructural retrofits is explained primarily by differences in the number of individuals at risk of death and injury.

Box 1 provides an example of where HAZUS®MH was used to calculate the benefits of mitigation for an earthquake-related project grant. Some calculations (i.e., the assessment of indirect economic benefits) were completed outside of HAZUS®MH, and these are clearly identified in the example.

6.3.1.2 Grants for Wind Project Mitigation Activities

Although several mitigation measures are included in the sample grants for the wind project grant stratum, the majority are hurricane storm shutters and saferooms. HAZUS®MH readily handles property benefit calculations for hurricane storm shutters. However, supplemental methodologies were developed by the study investigators to estimate property damage impacts of tornadoes and casualty impacts for both hurricanes and tornadoes (see Table 6-2). Benefit transfer methods were used to estimate environmental/historic benefits.

The simple average benefit-cost ratio for the 42 grants in the wind project stratum was 4.7, and the standard deviation was 7.0. The total benefit for this stratum is $1.3 billion. Individual grant benefit-cost ratios range from less than 0.05 for retrofit of a police department building to greater than 50, for a variety of utility protection measures.[66]

Several of the grants that had large benefit-cost ratios (>10.0), including all four outliers that exceeded 50.0, were cases of electric utility mitigation, such as relocating utility power lines below ground. In these cases, property damage savings were relatively small, but the business interruption savings were large. A downed power line, or a substation that has been disrupted because of a hurricane, can cause the economy of a city to come to a halt for days (Rose et al., 1997). Even the prevention of an outage of a few hours can pay for itself several times over in some instances.

Property loss benefits can be significant, with reductions measuring up to 4 times the cost of the retrofit. The sample average benefit-cost ratio associated with property loss reduction is 0.59. The estimated total reduction in property loss for all wind project grants (not just those in the sample) is $166 million.

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[66] Benefit-cost ratios outside these bounds were ignored for the purpose of calculating the stratum-average benefit-cost ratios, which results in a conservative estimate. The projects with a benefit-cost ratio less than 0.05 or greater than 50 are referred to here as outliers; all projects with benefit-cost ratio between 0.05 and 50 are referred to as the censored set. The bounds of 0.05 and 50 were initially selected somewhat arbitrarily. However, when one calculates the 1st and 99th percentiles of the lognormal distribution with the same moments as the censored set (±2.3 standard deviations), all members of the censored set have benefit-cost ratios within these 1st and 99th percentiles, so the bounds are in a way "stable." Note that the benefit-cost ratios of the censored set are approximately log normally distributed, passing a Kolmogorov-Smirnov goodness-of-fit test at the 5 percent significance level.

Box 1 HAZUS®MH EXAMPLE - Earthquake

Background

This is an example of where HAZUS®MH was used to calculate expected annual losses from earthquake with and without a mitigation activity. What is illustrated in this example are the input and output of HAZUS®MH and what calculations were done outside of HAZUS®MH to estimate the benefit-cost ratio associated with this mitigation activity. For this example, structural retrofit measures were implemented to improve the overall seismic resistance of a hospital.

HAZUS®MH Basic Input Information

Building Characteristics	Original Building	Retrofitted Building
Occupancy	Hospital	Hospital
Building Type	Concrete Shear-walls	Concrete Shear-walls
Design Level	Low	High
Building Quality	Inferior	Code

HAZUS®MH Models

Damage (median displacement for onset of damage, in inches)	Original Building	Retrofitted Building
Slight	0.96	1.2
Moderate	1.83	3
Extensive	4.74	9
Complete	12	24

Functional Loss		
None (Days)	0	0
Slight (Days)	2	2
Moderate (Days)	68	68
Extensive (Days)	270	270
Complete (Days)	360	360

Recovery Time		
None (Days)	0	0
Slight (Days)	20	20
Moderate (Days)	135	135
Extensive (Days)	540	540
Complete (Days)	720	720

Economic Factors		
Recapture Factor/Business Income	0.6	0.6
Recapture Factor/Wages	0.6	0.6

HAZUS®MH Iutput

Return Period	Peak Ground Acceleration (g)
100 Year	0.20
500 Year	0.38
1000 Year	0.50
2500 Year	0.66

Annualized Losses	Original Building	Retrofitted Building
Building Capital Loss	$235,608	$74,860
Direct Business Interruption Loss	$412,968	$69,083
SUBTOTAL ($)	$648,576	$143,943
Casualty - Level 1	0.3322*	0.0154*
Casualty - Level 2	0.1048*	0.0019*
Casualty - Level 3	0.0176*	0.0001*
Casualty - Level 4	0.0352*	0.0002*

*Absolute number of persons in a given casualty level per year.

Calculations Completed Outside of HAZUS®MH

Annualized Losses	Original Building	Retrofitted Building
Casualty value	$151,343	$1,435

Annualized Benefit	
Reduced Building Capital Loss	$160,748
Reduced Direct Business Interruption Loss	$343,885
Reduced Environmental Loss	$38
Reduced Casualty Loss	$149,908

Benefits and Costs in Project Year	
Project Year	1997
Amortization Period	100 yr (lifeline)
Discount Rate (Non-casualty only)	2%
Reduced Building Capital Loss	$6,927,974
Reduced Direct Business Interruption Loss	$14,820,877
Reduced Environmental Loss	$1,638
Reduced Casualty Loss	$12,618,519
Cost	$26,449,484

Benefits and Costs in 2004	
CPI 2004/CPI 1997	1.188
Reduced Building Capital Loss	$8,230,433
Reduced Direct Business Interruption Loss	$17,607,201
Reduced Environmental Loss	$1,946
Reduced Casualty Loss	$14,990,800
Total Benefit	$40,830,380
Cost	$31,421,987
Benefit-Cost Ratio	1.30

Casualty benefits apply to 25 grants in the wind stratum. All of these projects are either hurricane shelters or tornado saferooms. The hurricane grants involved mitigation of multiple properties, usually schools; however, not all of the schools are on the shelter inventory. The methodology calculated benefits for only those schools that also serve as hurricane shelters. Collectively, the schools that met this condition were able to shelter, at capacity, about 33,189 evacuees. The tornado grants involved the building of saferooms in public and private spaces, the majority of which were community shelters (sheltering 750 to 1,000) with one notable exception that sponsored the construction of saferooms in hundreds of private residences.

Considering both types of wind project grants — hurricane and tornado — together, mitigation activities reduced casualty losses in the sample by about $108 million, or an estimated $794 million for all wind project grants. The per-project mean casualty benefit is $4.3 million.

Some intangible benefits of shelters could not be quantified, and were therefore excluded from the benefit-cost analysis. Regardless of the financial benefit of sheltering, shelters are beneficial by reducing uncertainty and stress in those at risk. In addition, available hurricane shelter space keeps people off the highways during dangerous periods. More important, shelters offer the only safe haven for those without the financial means to take other protective measures.

Historical benefits were applicable to only one wind hazard grant: door and window protection for an historic town hall (a total estimated benefit of $115,000). For the wind project grant stratum overall, however, historic benefits contributed little to the average benefit-cost ratio.

Estimates of casualties avoided because of grants for wind mitigation project activities are high compared to the number of lives lost annually from high wind in the United States. In this study, the estimated casualties avoided are all tornado-related. Because the body of peer-reviewed scientific literature relating to probabilistic estimates of loss reduction from tornado mitigation is scant relative to that of other natural hazards covered in the study, the project investigators developed loss models without benefit of years of input from the scientific community in developing, testing and validating modeling techniques. (See Appendix H.)

Because of these issues, ATC contracted with Professor James McDonald of Texas Tech University, a noted wind engineering expert, to review and comment on the entire loss estimation methodology for tornado. Because of this review, changes were made to the methods used to quantify tornado impact areas. The Project Management Committee and the Internal Project Review Panel agree that the model used is logical. Avoided casualties have a limited effect on the aggregate results of the current study. The sensitivity analysis found that the benefit-cost ratio for the stratum of grants for wind project mitigation remained above one when casualty rates were reduced an order of magnitude lower than the estimated rates. If only 10 percent of the estimated benefits attributed to avoided casualties are counted, the benefit-cost ratio for grants for wind-project mitigation activities would decline from 4.7 to 2.1. Moreover, given the relatively small number and size of grants for wind mitigation, the benefit-cost ratio of all mitigation programs would be reduced from 4.0 to 3.8.

Box 2 provides an example of where relationships from HAZUS®MH were used to calculate the benefits of mitigation for a tornado-related project grant. Note that because HAZUS®MH currently does not address tornado hazards, almost all of the analysis was done outside of HAZUS®MH.

6.3.1.3 Grants for Flood Project Mitigation Activities

HAZUS®MH damage functions formed the basis for estimating property damage due to flooding. The hazard calculations, however, were performed outside of the HAZUS®MH flood module because this component was not available at the time of this study. Instead, an alternative methodology was developed that used a probabilistic approach to locate properties in the flood plane and to estimate the expected distribution of flood heights (see Section 4.3.1 for a description of this methodology). Casualties and displacement costs, and historic site and environmental benefits were calculated separately using the methodologies noted in Chapter 4. Because all mitigation measures applied to residential properties, no business interruption benefit was calculated.

The study investigators coded 71 grant files (consisting of 990 properties) into the project database. Approximately two-thirds, 625 properties, were geocoded through a combination of address matching tasks:

1. Matching to previously located properties in the NEMIS database;
2. Geocoding using TIGER street data; and
3. Matching addresses with geographic coordinates using online services such as MapQuest.

Out of the 625 geocoded buildings, 486 were within an acceptable distance of 3,567 meters[67] to allow mapping in the FEMA Q3 digital flood map and the USGS National Hydrography Dataset (NHD) stream data (see Appendix G for a description of the databases). Several projects were subsequently eliminated from the analysis because of insufficient data. A final selection of 483 properties corresponded to 22 grants. For each flood grant, only properties that matched all the above criteria were analyzed for direct property damage.

The number of geocoded properties in a single grant ranged from 1 to 133, with a mean of 42 and a standard deviation of 33. The property benefits realized for grants range from $0.19 million to $1.1 million. The average benefit per property ranged from $0.13 to $0.74 million, with an average benefit of $0.28 million, and a standard deviation of $0.14 million. The only significant outlier was the acquisition of a school, with a total benefit of $18.7 million.

Grants for flood acquisition projects also reduce the societal impacts of flooding by reducing injuries to the residents of the properties. For the flood project grant stratum, 22 grants had enough data to estimate casualty reduction benefits. The grants varied in size, with some mitigating many properties and others only a few. Overall, buying these properties reduced approximately 68 injuries for a total benefit of $12.3 million. On average, the 22 projects have a

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[67] 3,567 meters was chosen because it corresponds to the maximum geocoding error associated with rural areas.

Box 2 USE OF HAZUS®MH DAMAGE FUNCTIONS - Tornado

Background

HAZUS®MH damage functions were used to help calculate the benefits (i.e., reduction in number of casualties) associated with shelter installations, i.e., saferooms. In this case, the hazard being mitigated was tornado wind. Because HAZUS®MH is not currently set up to estimate tornado losses internally, the project investigators used the basic wind damage functions in HAZUS®MH (that are used for estimating the effects of hurricane wind) and applied these functions using an existing tornado risk assessment methodology (see Appendix H for details). The following example illustrates how these damage functions were used for a masonry school in the Midwest. To define the hazard potential for this region, an historic tornado incident catalog developed by NOAA was used.

Step 1: The tornado track data were aggregated to one-degree latitude by one-degree longitude grids. The count of tornado vectors by Fugita rating was extracted for the grid that contained the site location. The data were then normalized by the number of years surveyed in the NOAA dataset and adjusted using a linear multiplier for undercount.

Incidence of Tornados

|	F-1	F-2	F-3	F-4	F-5
Total	39	13	16	2	0
Per Year	1.2675	.4225	.52	.065	.0

Step 2: A buffer was calculated for each tornado vector that represented the drop-off in wind speed with increasing distance from each tornado path. For each buffer, the length and width of degradation by Fujita scale was used to calculate a total degradation matrix. This step results in an (annualized) exposure area (sq. kms.) associated with each wind speed. Summing these exposure areas by wind speed and dividing by the total grid area yields an estimate of the annualized probability of the structure being exposed to a given wind speed.

Annualized Exposure Areas by Wind Speed

	100 mph	150 mph	200 mph	250 mph	300 mph
F-1	.061811	0	0	0	0
F-2	.103917	.054265	0	0	0
F-3	.552378	.289046	.175237	0	0
F-4	.209148	.13194	.060325	.037042	0
F-5	0	0	0	0	0
Total	.927253	.475251	.235563	.037042	0
Freq.	.000235	.000120	.000060	.000009	0

Step 3: HAZUS®MH damage functions were used to estimate the expected damage by damage state. The annual wind speed probabilities provided in Step 2 were multiplied by the probability of being in a given damage state. This resulted in the following damage state probabilities: minor: 2.87×10^{-4}, moderate: 1.12×10^{-4}, severe: 7.39×10^{-5}, and destroyed: 7.17×10^{-5}.

HAZUS®MH Damage Functions
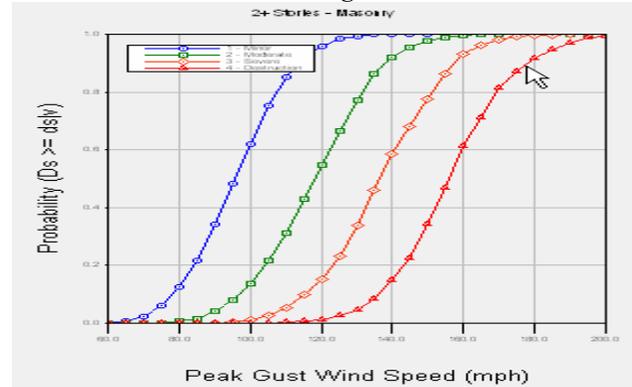
Step 4: ATC (1985) injury and death rates, as applied by the FEMA Benefit-Cost Analysis toolkit, were used to estimate the number of injuries and deaths from tornado wind. These rates were multiplied by the (annualized) damage state probabilities above. For purposes of quantifying exposure, an average of 300 individuals were assumed to the shelter.

ATC (1985) Injury and Death Rates

	Minor injury	Major injury	Death
Minor	0.0001	0.00001	0
Moderate	0.0012	0.00016	0.00004
Severe	0.06857	0.00914	0.00229
Destruction	0.4	0.4	0.2

Step 5: Casualty rates were then converted into dollar amounts using $17,000 for minor injuries, $180,000 for major injuries and $3,000,000 for deaths. The value of avoided casualties for this sample is compared to the cost of the tornado mitigation projects to yield the benefit cost ratio.

Benefit-Cost Calculations

Annualized Avoided Casualty Benefits	$8,279
Discount Rate (Casualty)	0%
Amortization Rate	50 years
Total Casualty Benefit	$413,950
Project Cost	$327,000
Benefit Cost Ratio	1.27

mean benefit of $0.56 million and standard deviation of $0.85 million. The large project standard deviation results from the large grant size range.

The majority of the grants in the flood project grant stratum were for residential structures that had experienced repeated flooding. Costs associated with residential flooding included displacement costs for the families to relocate while their homes underwent repair. By buying out repeatedly flooded properties, mitigation activities reduced displacement expenditures. Twenty-two sampled grants included sufficient information to estimate displacement costs. The total sampled stratum benefit is $2.3 million.

Sixteen of the flood mitigation grants yielded environmental benefits, and none yield historical benefits. Fourteen of the environmental benefits pertained to establishing wetlands following the removal of structures, rather than direct environmental benefits of reduced flooding per se. The environmental benefits of these grants were estimated by applying wetland values from the literature to each acre created. Conservative assumptions were made about the wetland acreage created for each property purchased, the percentage of these acres that actually function as wetlands, and the number of years that the acreage would function as such. Strictly speaking, these are side-effects of mitigation, rather than intended consequences. This report could have listed them as offsets to mitigation costs, but it is less confusing to list them under benefits.

The grant with the highest environmental benefit was for the purchase and removal of 262 flooded properties (approximately $0.32 million), while the lowest benefit was for the purchase and removal of one flooded property (approximately $6,000). The average environmental benefit associated with these 16 grants is nearly $96,000.

The total of all benefits realized for each grant ranged from $0.19 to $116.5 million, with a standard deviation of $27.3 million. The high standard deviation is directly attributable to the differences in the number of acquisitions.

All individual flood grants had benefit-cost ratios greater than 1.0, with an average benefit-cost ratio of 5.1, a minimum of 3.0, a maximum of 7.6, and a standard deviation of 1.1.

6.3.2 Sampled Grants for Process Mitigation Activities

This section presents the results for grants for process mitigation activities. The reader is reminded that process grants do not yield benefits themselves, but rather provide the basis for subsequent mitigation action. The benefits estimated here reflect only a portion of eventual benefits, the cost of which is often borne by nonfederal government agencies or the private sector. The essence of the process benefit estimation procedure is that grants for process mitigation activities have the same benefit-cost ratio as the mitigation activities that they eventually inspire. The analysis was based on the "surrogate benefit" approach presented in Sections 2.3 and 4.3.5.

Only the following major types of process activities were evaluated:

> 1. Information/warning (risk communication),

2. Building codes and related regulations, and

3. Hazard mitigation plans.

These three types of activities accounted for more than 85 percent of all process grants.

6.3.2.1 Grants for Earthquake Process Mitigation Activities

Twenty earthquake grants for process mitigation activities were evaluated. The average benefit-cost ratio of the sample is 2.5. Benefit-cost ratios for individual grants ranged from 1.1 for an engineering task force, to 4.0 for several grants for hazard mitigation plans and building codes. The surrogate benefit methodology analyzes each grant in its entirety and does not separate out the different types of benefits as was done for grants for project mitigation activities. The methodology does not lend itself to the calculation of the standard deviation of benefit-cost ratio, so that figure was omitted here. The majority of grants for earthquake process mitigation activities are for mitigation plans and improvement of building codes and regulations. The only grant for information activities was for vulnerability evaluations.

6.3.2.2 Grants for Wind Process Mitigation Activities

Twenty-one wind-related grants for process mitigation activities were evaluated. The average benefit-cost ratio is 1.2. Individual grant benefit-cost ratios ranged from 1.1 for risk communication activities to 1.4 for evaluation and training activities. Ten of the grants in this stratum were for hazard mitigation plans, and nine were for risk communication activities. The standard deviation of benefit-cost ratio was omitted because the surrogate benefit methodology does not lend itself to this calculation.

6.3.2.3 Grants for Flood Process Mitigation Activities

Only six grants for flood process mitigation activities were evaluated. The small number reflects the fact that the majority of grants for flood hazard process mitigation originally sampled were Project Impact grants, which were subsequently dropped from the benefit-cost analysis of FEMA grants study component because the files lacked sufficient data for a complete analysis. The average benefit-cost ratio for this stratum is 1.3, with little variation across individual grants. Five of the six grants were for mitigation plans and the other was for streamlining a building permit process. Again, the standard deviation of benefit-cost ratio for was omitted.

6.3.2.4 Summary of Results for Process Mitigation Activity Grants

A conservative estimate of the benefit-cost ratio for most grants for mitigation planning is about 1.4 (for a further explanation of this and other benefit-cost ratios used in this analysis the reader is referred to Section 4.3.5 and Appendix K). This estimate is based on the Mecklenburg (Canaan, 2000) studies, the study by Taylor et al. (1991), and the URS Group (2001) report, which is most applicable to multihazard grants. For grants for activities involving building codes a conservative estimate is higher than for multihazard grants, at a value of approximately 4. This estimate is an average based on the lower benefit-cost ratios provided in the studies by Taylor et al. (1991), Porter et al. (2004), and Lombard (1995). The estimate is likely conservative because of the very wide range of potential benefit-cost ratios estimated for actual adopted

building codes and savings in property damage from hurricanes of different size categories, including a few very high benefit-cost ratios for building codes (Lombard, 1995). With regard to a grant for seismic mapping, another estimate to confirm this range for the benefit-cost ratio is 1.3 based on the Bernknopf et al. (1997) study of the value of map information, which assumes that property value changes fully capitalize the hazard disclosure effects via the housing market.

Grants for building code activities likely will have a larger benefit-cost ratio than grants for information/warning and hazard mitigation plan activities. If a grant is inexpensive, it is quite likely that its net benefits will be positive, based on the Litan et al. (1992) study of earthquake mitigation, which found average benefit-cost ratios of about 3. Therefore, any small grant for process activities that does not have negative consequences in obtaining mitigation will only slightly raise costs and, therefore, only slightly reduce the benefit-cost ratios in this category. As Lombard (1995) notes, the benefit-cost ratio in some cases (e.g., smaller homes), and some hurricane categories (on a scale of 1 to 5), could be very large. An example is a benefit-cost ratio of 38 for anchorages for a Category 2 hurricane. Lombard's ratios are based on actual costs of mitigation, not related to grants per se, and there is no way to know how the probability of adopting specific building codes is changed by the grant.

Based on logic and effectiveness found in other contexts (Golan et al., 2000), there is reason to believe that grants for process mitigation activities provide positive net benefits in many situations. Project mitigation activities in many cases would never take place if a process activity had not generated the initial plan or building code that led to implementation. A common sense conclusion is that when net benefits from mitigation in a particular category, exclusive of a grant process for activities, are large, then a small grant certainly cannot reduce the net benefits by much; hence, any grant in that category is likely to be positive. However, when actual mitigation was quite costly, it was less likely that a grant for process activities was going to lead to positive net benefits.

Several caveats are warranted. First, in the literature search, no studies were found that specifically and clearly estimated the benefits of a hazard mitigation process activity. As noted in this report, to do so would require knowledge of how the probability of decision makers adopting a mitigation strategy changed after implementation of a process activity. Possible key differences have been noted between radon risk communication and a natural hazard risk warning. In general, the information that is available, even for conventional natural hazards, largely pertains to benefits and costs for mitigation projects or mitigation costs in general, i.e., not related to any grant activity. Second, there is still not enough information in the literature on the effectiveness of process activities to induce adoption of a mitigation action to generalize in the above categories. Third, blanket categorical benefit-cost ratios are unwise. Last, there is regional variation in rates of adoption of mitigation practices because of differences in conditions, experience, and perceptions (see the community studies discussion in Section 5).

6.4 Extrapolation of Sample Results to Population

The results presented in previous sections were scaled to the population of grants using the arithmetic mean approach described in Section 4.5.3. These population totals are presented in Table 6-3 for grants for project and process mitigation activities. The results indicate that the present value discounted benefits for FEMA hazard mitigation grants between mid-1993 and mid-2003 is $14.0 billion. This is juxtaposed against grant costs of $3.5 billion, for an overall

benefit-cost ratio of 4.0. Table 6-4 summarizes the calculation of stratum benefit-cost ratio. The benefit-cost ratios for project mitigation activities in descending size are 5.1 for flood, 4.7 for wind, and 1.4 for earthquake. Benefit-cost ratios are the reverse order for grants for process mitigation activities, with 2.5 for earthquake, 1.7 for wind, and 1.3 for flood.

Table 6-3 Mitigation benefits and sample size by hazard (in 2004 dollars)

Hazard	Type	Population		Sample	
		Count	**Benefits ($M)**	**Count**	**Benefits $M)[1]**
Wind	Project	1,190	1,307	42	219
	Process	382	161	21	44
Flood	Project	3,404	11,172	22	388
	Process	108	17	6	2
Earthquake	Project	347	1,194	25	365
	Process	48	198	20	93
Total		5,479	$14,049	136	$1,111

[1]The reader should *not* expect that (stratum sample benefit) = (stratum sample cost) x (stratum average BCR), because of the sampling and scale-up strategy discussed in sections 4.5.1 and 4.5.3. Stratum BCR is taken as $1/n^*$ (BCR_i), where BCR_i = (sample i benefit)/(sample i cost), and n = count of grants in the stratum sample. The BCR for each grant in the stratum sample is weighted equally. Grants are sampled from the population so that more-costly grants are more likely to be selected for sampling, with likelihood of being selected for the sample approximately proportional to cost. This procedure for sampling grants and scaling up to the population was found to produce lower error and lower uncertainty than randomly sampling grants from the stratum with equal probability, summing their benefits, summing their costs, and taking the resulting ratio as the estimate of the population's BCR for that stratum. Furthermore, it should *not* be expected that (total population benefit)/(total population cost) = (total sample benefit)/(total sample cost), because of the sampling and scale-up technique.

Table 6-4 Scale-up of results to all FEMA grants
(all $ figures in 2004 constant dollars)

	Project Grants			Process Grants			Total
	Quake	**Wind**	**Flood**	**Quake**	**Wind**	**Flood**	
Total grant cost ($M)	867	280	2,204	80	94	13	$ 3,538
Total grant benefit ($M)	1,194	1,307	11,172	198	161	17	$ 14,049
Total benefit-cost ratio (BCR)*	1.4	4.7	5.1	2.5	1.7	1.3	4.0
Standard deviation of BCR	1.3	7.0	1.1	n.a.	n.a.	n.a.	n.a.

*Row 2 (benefit) divided by row 1 (cost) equals row 3 (benefit-cost ratio)

n.a. = not applicable because of estimation method used

As shown in Figure 6-1, in terms of contribution to the benefit-cost ratio overall, casualty reduction was by far the dominant factor in earthquake and wind, and avoidance of property damage was the dominant factor in flood. This is attributable to a great extent to the life safety feature of most earthquake and hurricane/tornado project grants, and the property emphasis of flood grants (in addition to the longer warning time for the latter). Given the sample studied, business interruption avoidance was significant in earthquake and wind, but not for flood. This stems from the fact that the vast majority of flood project grants were for buyouts of residences

in floodplains. Environmental and historic benefits proved to be very minor in dollar terms, but still do affect a large number of people in each affected community.

6.4.1 Breakdown of Results

The results are summarized by hazard type in Table 6-5, which shows that overall, mitigation for each hazard has a benefit-cost ratio greater than one, with flood being the most cost-beneficial (BCR = 5.0). Table 6-6 also summarizes the benefit-cost analysis results by major mitigation type. It shows that both project and process activities are cost beneficial, with projects having an average benefit-cost ratio of 4.1, and processes having an average benefit-cost ratio of 2.0. Overall, flood grant benefits (both project and process) represent 80 percent of the total FEMA grant benefits. Wind and earthquake benefits each represent approximately 10 percent of the total.
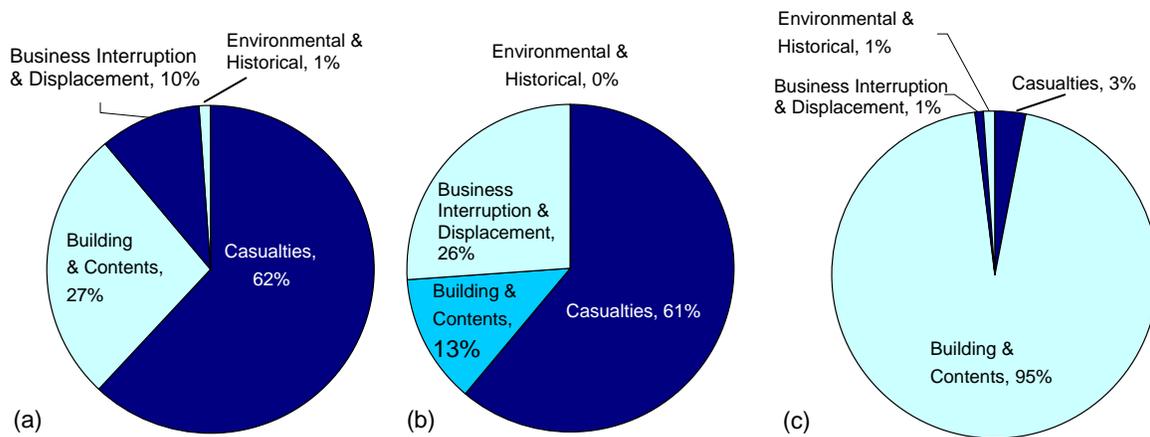

Figure 6-1 Contribution to benefit-cost ratio by factor for (a) earthquake, (b) wind, and (c) flood.

Table 6-5 Summary of benefits and costs by hazard

Hazard	Cost ($M)	Benefit ($M)	Benefit-Cost Ratio
Earthquake	947	1,392	1.5
Wind	374	1,468	3.9
Flood	2,217	11,189	5.0
Total	$ 3,538	$14,049	4.0

Table 6-6 Summary of benefits and costs by type of mitigation activity

Type	Cost ($M)	Benefit ($M)	Benefit-Cost Ratio
Project	3,351	13,673	4.1
Process	187	376	2.0
Total	$3,538	$14,049	4.0

In assessing the results, recall that grants for process mitigation activities (including Project Impact) represent only 10 percent of the total number of FEMA grants in the NEMIS database (the total population). Moreover, they represent only about 5 percent of the total FEMA grant

expenditures. As shown in Table 6-6, benefits from grants for process mitigation activities represent 2.7 percent of FEMA grant total benefits to the nation. This is consistent with the result that the benefit-cost ratio for grants for project mitigation activities, which is estimated to be twice as high as for grants for process activities.

Benefit-cost ratios vary significantly across hazards. One major reason is that the type of avoided damage differs significantly between earthquakes, hurricanes, tornados, and floods. For example, 95 percent of flood benefits are attributable to avoided losses to structures and contents, and only three percent is for casualty reduction, as opposed to casualty reductions slightly over 60 percent each for the cases of earthquake and wind hazards. The cost-effectiveness of measures to reduce property damage is higher than that for reducing casualty in the grants sampled in our study. This is due in part to the lower variability of factors affecting structures (which are of a fixed location, size, etc.) than of casualties (where occupancy rates vary by time of day), thereby making it harder to protect the latter.[68] In a similar vein, a higher proportion of wind mitigation grants are for the purpose of reducing the vulnerability of electric utilities to hurricane and tornado winds, than is the case for earthquakes. The largest individual grant benefit-cost ratios found in our study stemmed from reduced business interruption associated with damage to utilities.

Also, flood mitigation grants have a higher probability of success, and hence a higher benefit-cost ratio because they pertain to properties with known histories of vulnerability in the heart of floodplains, and recurrence of floods in a given location is much more certain than for other hazards. Finally, given that process mitigation grants have lower benefit-cost ratios than project mitigation grants across all hazard categories, the fact that process grants represented only 0.15 percent of total flood project mitigation benefits, in contrast to 1.2 percent of wind mitigation grant benefits, kept the flood process mitigation grants from pulling down the overall flood benefit-cost ratio as much as they did for overall wind benefit-cost ratio.

6.4.2 Deaths and Injuries

Table 6-7 highlights the reduction of casualties as a result of the mitigation activities conducted under the grants in the sample and for the entire population of grants. Because the NEMIS database does not include data on the number of people exposed, scale-up requires estimates based on proportional grant costs. The ratio of sample grant injury reduction to sample grant costs was applied to population costs to estimate national reduction by stratum.

Mitigation grants will prevent an estimated 4,699 injuries and 223 deaths over the assumed life of the mitigation activities, which in most cases is 50 years. As illustrated in Table 6-7, grants for wind mitigation activities will prevent the most injuries (1,790) and the most deaths (156). As with any casualty figures, these estimates require caution, as they are based on a scientifically sound methodology, but are difficult to validate because of limited available empirical data.

The grants examined not only benefit society by reducing financial expenditures, but also, and equally as important, reduce associated stress and family interruption. While consideration was

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[68] For example, mitigation grants to replace pendant lighting in schools provided potential protection but did not always yield actual benefits, as in the cases of the Northridge and Loma Prieta earthquakes, which took place when schools were not in session.

not able to be given to the financial benefit of these reductions, they are an important component of the benefit of mitigation.

6.4.3 Net Benefits to Society

As noted above, the overall benefit to society for all 5,479 grants is approximately $14.0 billion, and the cost to society is $3.5 billion. The net benefit to society of FEMA-funded mitigation efforts is thus $10.5 billion, which includes the financial benefits and dollar-equivalent benefit of saving 223 lives and avoiding 4,699 nonfatal injuries (Table 6-7).

**Table 6-7 Estimated reduction in casualties by grants for
both project and process mitigation activities in
sample and population of grants**

	Injuries	Deaths
Earthquake sample	542	26
Population	1,399	67
Flood sample	63	0
Population	1,510	0
Wind sample	275	24
Population	1,790	156
Total samples	880	50
Population total	4,699	223

6.4.4 Impacts on the Federal Treasury

The methodology described in Section 4.5.4 was applied to estimating the potential future savings to the federal treasury of FEMA hazard mitigation grants. The two major categories of savings are:

1. Reductions in government spending on disaster recovery and future natural hazard mitigation.

2. Recouped federal taxes for reductions in individual and business casualty loss and increase in federal tax revenues from income subject to tax from individuals who avoided death or injury.

Individual components of these savings are listed in the Category column of Table 6-8, along with the sources of the base data. Adjustments made to the data are identified in the third and fourth columns and in the table notes. Examples of more straightforward adjustments include annual averaging and present value calculations. Other adjustments required that assumptions be made based on indications in the literature regarding insurance coverage and the ratio of government and nonprofit sector to total business losses. (Average tax rates are used rather than marginal rates because the latter would have required determination of the income status of all disaster victims.) In all, 10 different categories of savings are estimated.

Table 6-8 Annual potential savings to the Federal Treasury

Category	Base (2004 $ in millions)	Adjusted Base (2004 $ in millions)	Factor	Savings (2004 $ in millions)	Source of Base Data
Federal Government Expenditures Saved					
Public assistance	2,240.9	n.a.	.174[1]	389.9	FEMA (2005)
Individual assistance/human services	889.8	n.a.	.174	154.8	FEMA (2005)
Mission assignments /standby grants	126.6	n.a.	.174	22.0	FEMA (2005)
FEMA administrative costs	594.6	n.a.	.174	103.5	FEMA (2005)
Mitigation grants and contracts	386.7	n.a.	.174	67.3	FEMA (2005)
U.S. Small Business Administration default and administrative costs	463.4	n.a.	.174	80.6	SBA (2005)
U.S. Army Corps of Engineers emergency measures	104.8	n.a.	.174	18.2	USACE (2005)
Subtotal	n.a.	n.a.	n.a.	$836.3	
Federal Tax Revenues Recouped					
Individual income tax casualty loss deduction	1,061.3[2]	530.7[3]	.171[4]	90.7	This study
Individual income tax payments related to reduction in injury and death	208.9[5]	n.a.	.171	35.7	This study
Corporate income tax payments related to reduction in casualty loss business interruption	108.9[6]	23.0[7]	.252[8]	5.8	This study
Subtotal	n.a.	n.a.	n.a.	$132.2	
Grand Total	n.a.	n.a.	n.a.	$968.5	

n.a. — not applicable

[1]Ratio of average annual property damage and casualty (death and injury) reduction from grants for project and process mitigation activities in this study (present value for 50 years discounted at 2 percent, which amounts to $1.32 billion) divided by average annual property damage and casualty values from natural hazards in the U.S. ($7.6 billion in 2004 dollars), from University of South Carolina (2005).

[2]Based on avoided residential property damage from floods from average annual mitigation (present value discounted at 2 percent).

[3]Applied to uninsured household property damage associated with floods (FEMA-funded mitigation applicable to individual taxpayers pertains only to flood hazard). Assumes 50 percent of damage was uninsured. Proportion of individual property loss avoided to total property loss avoided from floods was based on ratio of private to total (private and public) number of properties mitigated. A further 10 percent reduction was assumed to cover people who do not itemize deductions and to cover the exclusion of individual casualty loss that can be deducted.

[4]10-year average individual tax rate for 1993-2002 (IRS, 2003; 2004a,b).

[5]Based on avoided death and injury from earthquake, wind, and flood from average annual mitigation (not discounted).

[6]Based on avoided private (not including public and nonprofit sector building) property damage and business interruption (including displacement costs) from earthquake and wind (FEMA flood mitigation had minimal application to business) from average annual mitigation (present value discounted at 2 percent). Assumes property damage to private sector was 1.0 percent of annual average total property damage in case of earthquake and wind. Assumes that private for-profit sector business interruption loss for earthquake and wind was 77 percent of total business interruption loss (based on national average of business activity in the for-profit sector).

[7]Assumes that 50 percent of business losses are insured.

[8]10-year average corporate tax rate for 1993-2002 (IRS 2003; U.S. Department of Commerce, 2003).

The estimate of the present value of total annual savings in terms of federal government expenditures in present value terms is $836.3 million. The largest category is FEMA Public Assistance ($389.9 million) and the smallest is U.S. Army Corps of Engineers emergency measures ($18.2 million).

The estimate of the present value of total annual savings in terms of recouped federal taxes is $132.2 million. The largest category here is income tax payments by those individuals who are spared casualty loss (in tax parlance, this refers to property rather than death or injury) ($90.7 million) and the smallest category is corporate income tax payments relating to reduced casualty loss and reduced business interruption to private entities ($5.8 million). The latter is rather small because the vast majority of federal mitigation grants go to public institutions, which do not have to pay federal business related taxes. The majority of the tax revenue benefits stem from utility customers.

The present value of total annual potential future savings to the federal treasury is $968.5 million. The average annual FEMA expenditure for hazard mitigation in the population of grants for which benefits were estimated in this study is $265.4 million (the federal share of the average annual cost of mitigation grants is 75 percent of $353.8 million). This means that on average every $1 of FEMA expenditures generates a present value of future savings to the federal treasury of $3.65. This result indicates that the FEMA hazard mitigation program more than pays for itself in terms of cost to the federal treasury. Also, this is to a great extent separate[69] from the benefits of avoided hazard losses to the American people.

The reader should bear two things in mind. First, the majority of the savings in Table 6-8 are not reductions in costs to society as a whole, but rather are transfers from one entity to another. Transfers do not represent the avoided destruction of real resources (e.g., buildings, human casualties, wetlands), but are only a shift of money from one entity to another, as in the payment of a tax or subsidy. Real resource savings are counted in the benefit-cost analysis. The entries in Table 6-8 that are not merely transfers are various administrative cost reductions and resources actually used in recovery and for future mitigation. Second, the savings are *potential*. Reduced hazard losses make private and public expenditures for recovery efforts unnecessary for those hazards that are mitigated. However, substantial unmitigated hazard losses may still attract federal and private assistance. These payments may not actually be reduced over the short term by the amount of the full potential savings identified in this report. The sum total of hazard recovery *needs*, however, is definitely reduced and is increasingly likely to lead to reductions in recovery spending in the long run.

The base numbers in this analysis reflect actual government expenditures and estimates of hazard losses presented in this report. Many of these bases required no adjustments for application of savings factors applied in this analysis, and the few that did were adjusted by standard tax code deductions. Some savings factors are simply average tax rates. The exception is the 17.4 percent annual hazard reduction rate, which was based on estimation of the present value of categories of commonly measured (property damage, death, and injury) avoided hazard losses in relation to like categories of total annual hazard losses (see also Section 4.5.4). The remaining assumption — that federal expenditures on disaster recovery is potentially reduced in full proportion to hazard losses — is one that can be argued both ways. The exact outcome is likely to lie somewhere between the extreme positions of no decrease, or a full decrease, in spending. This is the main reason why savings have been labeled as "potential." However, as mitigation cumulates, the reduced need for post-disaster expenditures will surely be evident.

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[69] The overlap is limited to actual resource use for disaster recovery and natural hazard mitigation.

The estimates of savings are also in keeping with the objective of erring on the side of conservatism. Consequently, potential increased tax revenue associated with a possible reduced level of philanthropic giving, lower tax deductions, and potential reductions of HUD Block Grants were not included in this analysis.

6.5 Sensitivity Analysis

Sensitivity analyses were performed on the parameters listed in Table 4-11. Figures 6-2, 6-3, and 6-4 illustrate how making different assumptions affects the total estimated benefit for those that revealed the greatest range of sensitivities. In each figure, there is a solid vertical line that represents the baseline (best) estimate of total benefit for all mitigation grants for that hazard. There is a dashed vertical line that represents the total cost for mitigation grants for that hazard.

Each black bar in the diagram reflects what happens to the total population estimated benefits for that hazard if one parameter (number of occupants, discount rate, etc.) is changed from a lower-bound to an upper-bound value. A longer bar reflects greater sensitivity of benefit to that parameter. Here, the "lower-bound" and "upper-bound" values are estimates of the 4th and 96th percentile values of the parameter in question. The parameters are sorted so that the longest black bar — the one for the parameter to which the benefit is most sensitive — is on top, the next most sensitive is second from the top, etc. The resulting diagram resembles a tornado in profile, and is called a tornado diagram.

The diagram does two things: first, it shows the conditions under which benefit exceeds cost. Second, the baseline benefit and the values of benefit at the ends of the bars can be used to estimate the parameters of a probability distribution of total nationwide benefit. These parameters include the mean and standard deviation of total benefit, among others. To calculate them, a mathematical procedure was used called an "unscented transform"[70] (Julier and Uhlman, 2002). Using this procedure, it was possible to estimate the probability that the "true" total nationwide benefit for a given hazard exceeds the cost. The unscented transform makes it unnecessary to vary several parameters simultaneously; it accounts for the probability that several parameters will be greater or less than their best-estimate values.

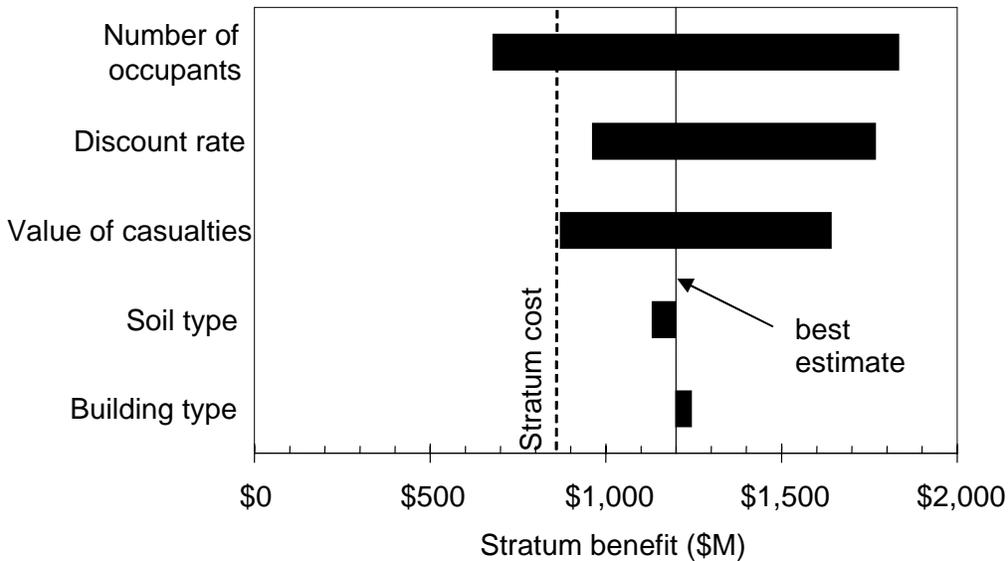### 6.5.1 Grants for Earthquake Project Activities

Results for earthquake project mitigation benefits are illustrated in Figure 6-2. In the figure, the solid vertical line at $1.2 billion reflects the baseline benefit for earthquake project grants; the dashed line at $0.87 billion represents the cost of those grants. Total benefit is most strongly sensitive to number of occupants, then to discount rate, then to value of casualties. Notice that the only bar that crosses below the cost of mitigations is the first one, number of occupants. In all other cases, benefits exceed costs.

Using the unscented transform, it was found that the expected value of benefit from earthquake mitigation grants is $1.3 billion (approximately the same as the baseline figure of $1.2 billion). The standard deviation of benefit is $470 million. Assuming that benefit is lognormally

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[70] An unscented transform is a mathematical technique for selecting samples of set of uncertain variables, to estimate the mean value, variance, and other statistics of a function of those variables. The technique is far more efficient than random sampling (such as by Monte Carlo simulation), meaning that far few samples are required using the unscented transform than using random sampling to achieve the same level of accuracy.

distributed, the ± 1 standard deviation bounds of benefit are $850 million and $1.7 billion. Benefit exceeds cost with 83 percent probability. The expected value of benefit-cost ratio is 1.5, approximately the same as the baseline value of 1.4.
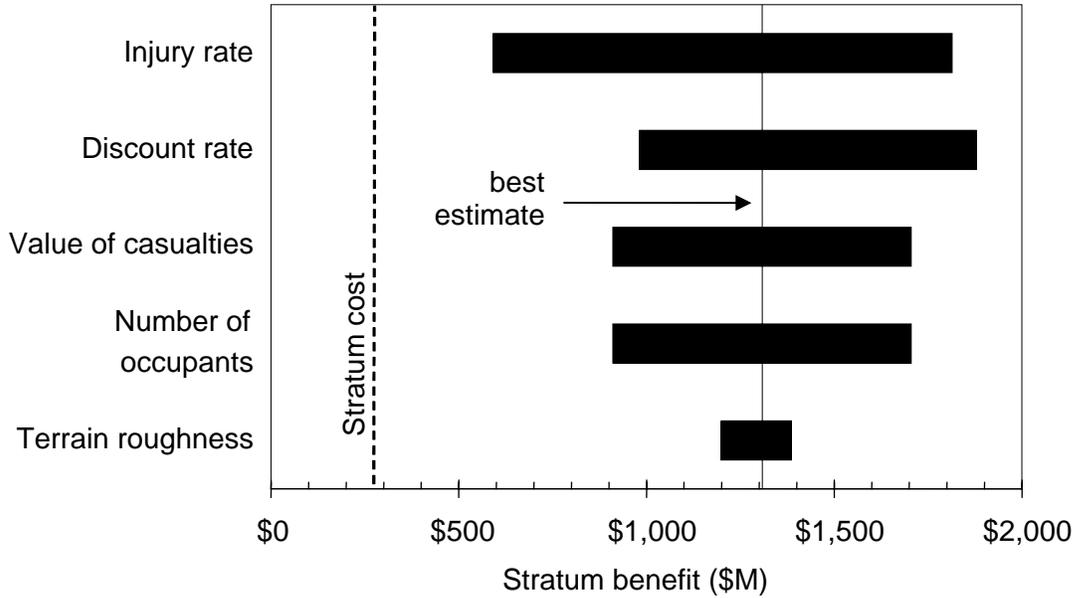

**Figure 6-2 Sensitivity of benefit to uncertainties
(grants for earthquake project mitigation activities).**

A word of caution regarding the comments about the probability that benefit exceeds cost. According to standard benefit-cost analysis, earthquake project grants *are* cost effective, because under baseline conditions, benefit exceeds cost by a ratio of 1.4:1. The additional diagram analysis merely acknowledges that the estimated benefit is uncertain, and that under most reasonable assumptions, benefits still exceed cost. Considering these uncertain parameters, earthquake projects are estimated to save $1.50 in reduced future losses for every $1 spent.

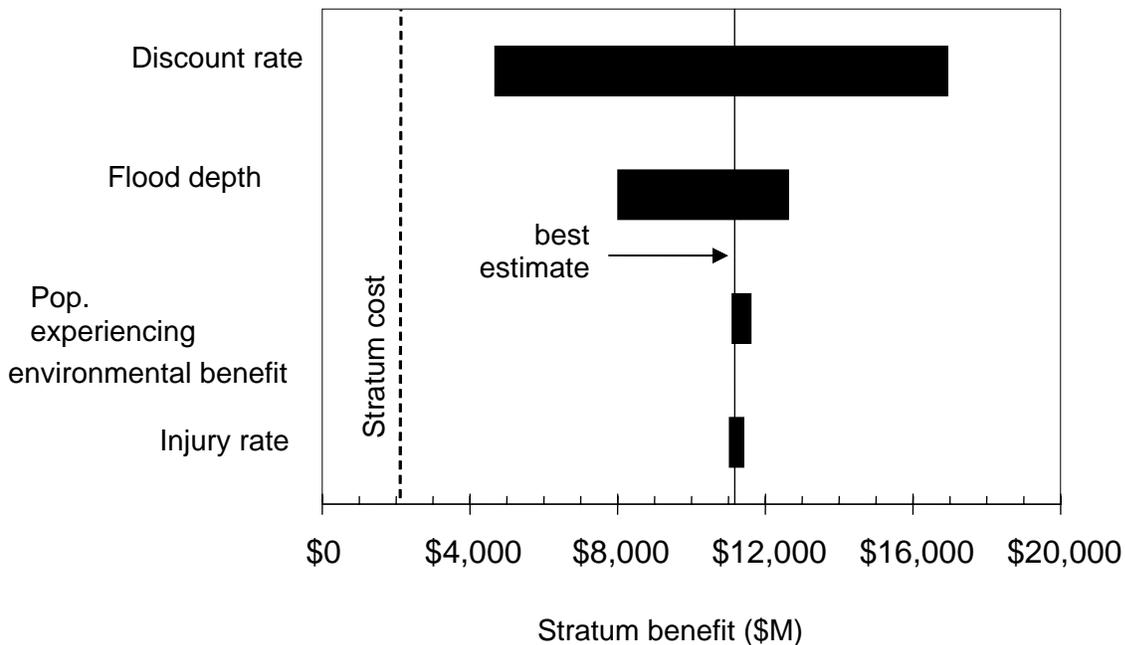**6.5.2 Grants for Wind Project Mitigation Activities**

Figure 6-3 shows the diagram for grants for wind project mitigation activities. In all cases, the benefit exceeds the cost. Wind project benefits are approximately equally sensitive to injury rate, discount rate, value of casualties, and number of occupants. The expected value of benefits is $1.3 billion, and the standard deviation is $560 million. Assuming a lognormal distribution, the ± 1 standard deviation bounds of benefit are $800 million and $1.8 billion. There is greater than 99 percent probability that the "true" benefit exceeds the cost, despite the uncertain parameters examined here. The expected value of benefit-cost ratio is 4.7. That is, every $1 spent on wind project grants is estimated to save almost $5.

**Figure 6-3 Sensitivity of benefit to uncertainties
(grants for wind project mitigation activities).**

6.5.3 Grants for Flood Project Mitigation Activities

Figure 6-4 shows the diagram for grants for flood project mitigation activities. Flood project benefits are most sensitive to discount rate, then to uncertainties in flood depth. In all cases, the benefit exceeds the cost, i.e., under all reasonable assumptions about the values of these parameters, flood project grants are estimated to be cost effective. The expected value of benefit is $11 billion, and the standard deviation is $3.8 billion. Assuming lognormal distribution, the ± 1 standard deviation bounds of benefit are $7 billion and $15 billion. There is greater than 99 percent probability that the "true" benefit exceeds the cost, despite uncertainties in the parameters examined in this study. The expected value of the benefit-cost ratio is 4.8. That is, on average every $1 spent on flood project grants is estimated to save almost $5.

**Figure 6-4 Sensitivity of benefit to uncertainties
(grants for flood project mitigation activities).**

6.6 Other Sensitivity Analyses

Sensitivity analyses were not performed for direct business interruption for two reasons. First, direct business interruption estimates were derived to a great extent from direct property damage. Although not perfectly correlated, further sensitivity analyses would probably have been redundant. Second, there were few factors that could be subjected to sensitivity analysis of direct business interruption in HAZUS®MH . Sensitivity analyses were performed for indirect business interruption with respect to the regional economy unemployment rate (as a proxy for excess production capacity). The analysis indicates that the overall stratum benefit-cost ratios are not sensitive to this parameter because of the small number of cases where business interruption was applied, the small size of indirect business interruption in all cases (except the few mitigation projects affecting utilities), and the narrow variation in this parameter.

The unemployment rate, as a proxy for excess capacity, is one of several sources of resilience to disasters factored into this study. Another is the recapture factor (the ability to make up lost production at a later date), which is automatically included in the HAZUS®MH Direct Economic Loss Module (DELM). This recapture factor was also included in the HAZUS®MH Extension (defined in Table 6-3) for utilities developed in this study, and in fact the recapture factor for services was increased in line with the study's conservative assumptions. Other aspects of resilience pertained to inventories, import of goods for which there is a shortage, and export of surplus goods. These were automatically computed in the HAZUS®MH Indirect Economic Loss Module (IELM). Resilience effects were not separated out, because that was not the focus of this study. The values provided by HAZUS®MH were used for these parameters (inventories, import and export of goods) and sensitivity analysis was not undertaken because HAZUS®MH

import and export resilience factors only affect indirect business interruption, which was relatively minor, and because inventories were not a factor in nearly all of the cases where direct business interruption was large (e.g., electricity cannot be stored). It was assumed that hospital inventories would not be significantly affected by most disasters, given the tendency of hospitals to place priority on this feature and to have emergency plans in place to meet shortages. This results in a narrow range in possible inventory holdings.

The savings to the federal treasury are robust as well. Although no formal sensitivity tests were performed here, these estimates (i.e., savings to the federal treasury) are based on government expenditure data, loss estimation data estimated in this study (and for which sensitivity tests were performed), and straightforward parameters like federal tax rates and insurance coverage.

6.7 Combining Sampling Uncertainty and Modeling Uncertainty

As has been noted elsewhere, the total benefit of FEMA grants is uncertain. It is desired to quantify and combine all important sources of uncertainty. This information can then be used to calculate two interesting parameters: confidence bounds for the total benefit of FEMA grants for each hazard and the probability that the "true" benefits exceed the cost. By "confidence bounds" is meant upper and lower bounds between which the "true" total benefit lies with any given level of probability. The uncertainty in total benefit of FEMA grants results from two principle sources:

1. Sampling uncertainty ─ Total benefits are uncertain because they are estimated from a sample (a subset) of FEMA grants, not the entire population of them. Here, sampling uncertainty is quantified in Table 6-4, via the standard deviation of benefit-cost ratio.

2. Modeling uncertainty ─ Total benefits are uncertain because a mathematical model of benefits has been created and applied, and that mathematical model has its own uncertain parameters. For this report, modeling uncertainty is quantified in Section 6.5, via the standard deviation of benefit.

As detailed in Appendix R, these two sources of uncertainty can be combined to estimate overall uncertainty in benefit of FEMA grants. Two observations are made:

1. Modeling uncertainty dominates total uncertainty so a larger sample would not improve the accuracy of the estimated benefits.

2. The results reaffirm the observation that grants for project mitigation activities produce benefits in excess of costs with high probability for all three hazards.

6.8 Conclusions

This chapter summarizes the application of several practical methods to estimate the benefits of FEMA-funded hazard mitigation activities. These are not necessarily the ideal methods that one might consider for this purpose, were data and time less constrained (see the Scoping Study report (ATC, 2003a) for a discussion of various alternative methods). However, they represent the best practical methods available given limitations of data and time.

This study estimated that total benefits to the nation of FEMA mitigation grants between mid-1993 and mid-2003 yielded a present discounted value of $14 billion. (Grants outside of this

date range and grants to mitigate risk from winter storm and some other hazards were not studied.) Compared to a cost of $3.5 billion, the overall benefit-cost ratio is 4.0. These results indicate that, on average, FEMA-funded project and process mitigation activities have benefit-cost ratios greater than 1.0 for all hazard types. In fact, for wind and flood projects, the benefit-cost ratios are 4.7 and 5.1, respectively. Grants for earthquake process mitigation activities have a high benefit-cost ratio of about 2.5 as well. Moreover, the sensitivity analyses performed indicate that these results are robust even to extreme variations in key parameters.

Potential annual savings to the federal treasury of these grants is estimated to be $969 million. Juxtaposed against grant costs, this means that on average every dollar of FEMA mitigation grant expenditures will potentially lead to an average of a $3.65 combination of reduction in future post-disaster relief and increased federal tax revenues. These results are robust as well.

The benefit-cost analysis of FEMA mitigation grants can be considered to have yielded lower-bound estimates for three reasons. First, the analysis used conservative assumptions regarding vulnerability of buildings, the scope of business interruption losses, and the extent of casualties. Second, "outliers" were excluded in calculating sample stratum benefit-cost ratios. Outliers with especially high benefit-cost ratios had the potential to significantly increase the sample mean benefit-cost ratio much more than outliers with low values had to decrease the sample mean. Third, several categories of the benefits of reduced losses were omitted because they could not be quantified. These include the avoidance of: several types of societal impacts related to psychological trauma; indirect property damage such as ancillary fires; environmental damage to complex ecosystems; air quality of burning debris; land-use and costs of reduced disposal of debris. It also excludes the outright benefits of the diffusion of hazard mitigation research and demonstration projects.

Chapter 7
STUDY RESEARCH FINDINGS

A summary of key findings from the benefit-cost analysis of FEMA mitigation grants and community studies is presented below.

1. **The net benefits of FEMA's hazard mitigation program to society as whole are positive.**

    This study estimated that total benefits to the nation of FEMA mitigation grants between mid-1993 and mid-2003 yielded a present discounted value of $14 billion. Compared to a cost of $3.5 billion, the overall benefit-cost ratio is 4.0. These results indicate that, on average, FEMA-funded project and process mitigation activities have benefit-cost ratios greater than 1.0 for all hazard types. In fact, for wind and flood projects, the benefit-cost ratios are 4.7 and 4.1, respectively. Earthquake process grants have a high benefit-cost ratio of about 4.0 as well. Moreover, the sensitivity analyses performed indicate that these results are robust, even to extreme variations in key parameters.

2. **A federal dollar spent on hazard mitigation potentially saves the federal treasury about $3.65.**

    The present value of annual savings to the federal treasury emanating from the FEMA mitigation grants studied is $968.5 million. When juxtaposed against the federal share of grant costs, a dollar spent on mitigation grants potentially will lead to an average savings of $3.65 in avoided post-disaster relief and increased federal tax revenues. This potential benefit to the treasury is in addition to the societal savings considered in the benefit-cost analysis. These results are robust as well.

3. **Synergistic activities occur in communities that have institutionalized their hazard mitigation programs.**

    In each of the eight communities studied, federal hazard mitigation grants were a significant part of the community's mitigation history. As shown in the activity chronologies developed for each community (Figures 5-1 through 5-8), the federal hazard mitigation grants often led to additional or synergistic activities. Interviewees in all communities thought the FEMAgrants were important in reducing community risk, preventing future damage, and increasing a community's capability to mitigate natural hazards. Most interviewees believed the grants permitted their communities to attain mitigation goals that might not otherwise have been reached. Interviewees also believed that the benefits of the mitigation projects went beyond what could actually be quantitatively measured. These included increased community awareness, esprit de'corps, and peace of mind. Virtually every interviewee believed that their community was better off as a result of FEMA mitigation project and process grants being completed.

4. **The findings above are judged to be robust, given an analysis of uncertainties and assumptions.**

The impact of uncertainties was analyzed through formal sensitivity studies and informal evaluations of methodological limitations and assumptions for he benefit-cost analysis of individual FEMA mitigation grants and grants within the context of communities,.   In the case of the benefit-cost analysis of FEMA mitigation grants, benefit-cost ratios remained above one in all sensitivity analyses (13 total cases), with one exception where the ratio was slightly less than one. In the community studies, an analysis of extreme lower-bound values resulted in about half of the cases remaining above one. The Validation and Quality Control Plan described in Appendix S was implemented as part of this study.