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Costs and Consequences of Flooding and the Impact of the National Flood Insurance Program

Camilo Sarmiento and Ted R. Miller

Pacific Institute for Research and Evaluation

October 2006

Prepared under subcontract to the American Institutes for Research
as part of the 2001–2006 Evaluation of the National Flood Insurance Program

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October 2006

REPORTS IN THE EVALUATION OF THE NATIONAL FLOOD INSURANCE PROGRAM

This Evaluation is composed of a series of reports assessing questions identified and prioritized by a steering committee about the National Flood Insurance Program. The reports of the Evaluation will be posted on the FEMA website as they are finalized. The website URL is http://www.fema.gov/business/nfip/nfipeval.shtm. The reports in the Evaluation are:

The Evaluation of the National Flood Insurance Program – Final Report
American Institutes for Research and NFIP Evaluation Working Group.

Assessing the Adequacy of the National Flood Insurance Program's 1 Percent Flood Standard. Galloway, Baecher, Plasencia, Coulton, Louthain, and Bagha, Water Policy Collaborative, University of Maryland.

The Role of Actuarial Soundness in the National Flood Insurance Program. Bingham, Charron, Kirschner, Messick, and Sabade, Deloitte Consulting.

Costs and Consequences of Flooding and the Impact of the National Flood Insurance Program. Sarmiento and Miller, Pacific Institute of Research and Evaluation.

Developmental and Environmental Impacts of the National Flood Insurance Program: A Review of Literature. Rosenbaum, American Institutes for Research.

The Developmental and Environmental Impact of the National Flood Insurance Program: A Summary Research Report. Rosenbaum and Boulware, American Institutes for Research.

An Evaluation of Compliance with the National Flood Insurance Program Part A: Achieving Community Compliance. Monday, Grill, Esformes, Eng, Kinney, and Shapiro, American Institutes for Research.

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Evaluation of the National Flood Insurance Program's Building Standards. Jones, Coulbourne, Marshall, and Rogers, Christopher Jones and Associates.

Managing Future Development Conditions in the National Flood Insurance Program. Blais, Nguyen, Tate, Dogan, and Petrow, ABSG Consulting; and Mifflin and Jones.

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The research described in this report was funded with Federal funds from the Federal Emergency Management Agency under contract # 282-98-0029 and under subcontract to the American Institutes for Research. The content of this publication does not necessarily reflect the views or policies of the Federal Emergency Management Agency, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.

A 30-year-old not-for-profit corporation headquartered in Calverton, MD, the Pacific Institute for Research and Evaluation specializes in basic science studies of the causes and origins of risky and anti-social behaviors, as well as the evaluation of policies and programs designed to reduce the incidence of risk-taking and mitigate its consequences. The hallmark of PIRE's activities is a proactive stance that promotes conceptually sound, scientifically supported, culturally sensitive prevention, mitigation, and loss compensation practices.

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Ted R. Miller, Principal Research Scientist and Director, Public Services Research Institute, Pacific Institute for Research and Evaluation directed the design of the Evaluation of the National Flood Insurance Program, as well as PIRE's work on the Evaluation itself. He has led more than 175 studies, including 75 economic analyses. Dr. Miller has 29 years of experience analyzing property and casualty insurance issues for the Federal government. He has been involved with flood insurance intermittently since the 1970s when he evaluated the capability and experiences of small communities in implementing the NFIP and associated building code and inspection systems. His recent research primarily probes risk levels, the costs of drowning and other preventable injury incidents, and the benefits of prevention from societal, employer, government, and insurer perspectives. He spent 20 years analyzing housing rehabilitation, low-income housing, economic development, and public finance issues. He received a Ph.D. in Regional Science (spatial economics), a Masters in City and Regional Planning, and a M.S. in Operations Research from the University of Pennsylvania, as well as a B.S. in Engineering from Case-Western Reserve University.

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ACKNOWLEDGEMENTS

The authors are grateful to many individuals for their assistance, comments, and insights. This includes Claudia Murphy, Mike Robinson, Marc Shapiro, Tom Hayes, Neil Blais, Pat Canning, Margaret Esnard, Larry Larson, Dennis Mileti, Frank Reilly, and Rich Tobin. We also thank consultant Maria Orlando for her design work early in this study.

EXECUTIVE SUMMARY

Background

On average, floods in the United States caused about $6 billion in damages annually between 1955 and 1999 including damages to private buildings, public facilities, and agriculture (University of Colorado 2001). However, standard homeowner policies do not include flood coverage, as private insurers historically have found it unprofitable to insure low-frequency, high-severity disasters such as floods. Until the establishment of the National Flood Insurance Program (NFIP) in 1968, the primary recourse for flood victims was federal government disaster assistance (FEMA, 2002, p.1). Congress adopted the NFIP in response to the ongoing unavailability of private insurance and continued increases in federal disaster assistance in order to provide federal flood insurance protection as well as to give local governments an incentive to adopt floodplain management regulations to mitigate losses from flooding in special flood hazard areas (SFHAs). The floodplain management regulations require newly constructed residences to be elevated above the base flood elevation (BFE) and nonresidential buildings to be elevated above or floodproofed (made watertight) to that elevation. These regulations apply to structures that were constructed or substantially improved after December 31, 1974, or after the effective date of the initial Flood Insurance Rate Map (FIRM) of a community, whichever is later.

Congress enticed communities to join the Program by offering affordable insurance rates in exchange for adoption of stricter ordinances and building standards for future construction. Discounted flood insurance policies were needed to enroll and retain those residents whose buildings had already, law-abidingly, been constructed in floodplains and that were built at elevations substantially below the BFE. These pre-FIRM structures are not subject to federally mandated floodplain management regulations unless they were repaired after substantial damage or were substantially improved post-FIRM. The NFIP charges actuarial rates to post-FIRM structures, discounted premiums, generally referred to as "subsidized," to pre-FIRM structures built below BFE, and actuarial rates to pre-FIRM structures built above BFE.

This study examines the cost effectiveness of the NFIP in reducing flood costs to residences in SFHAs as well as in reducing costs to taxpayers. It also examines how well the NFIP serves low-income households. The study answers fundamental questions about the costs and consequences of floods including (i) the distribution of the financial impact of flood costs by payer (government, individuals) under different levels of flood insurance penetration (i.e., with differing percentages of SFHA property covered by flood insurance policies); (ii) the impact of floodplain management on flood costs; (iii) the distribution of flood losses by income group; and (iv) costs of flooding to local economies and governments. It also provides insight into the effect of the NFIP on housing costs and on development in SFHAs including the effect of subsidies on pre-FIRM homes.

Methods

FEMA recently built and validated the Hazards U.S. Multi-Hazard (HAZUS) flood loss simulation model. By size of flood, this model estimates direct economic losses (building and contents losses), as well as indirect losses (relocation losses, wage losses, rental income losses) in a floodplain. The NFIP covers flood losses to buildings and contents, but it does not protect against the indirect costs of flooding (e.g., temporary housing) to residents. It also does not protect against a variety of other costs omitted from HAZUS, ranging from loss of life to loss of family photos and mementoes, from stress and depression to disruption of public services.

HAZUS stores and analyzes most data at the Census Block level, with the ability to aggregate blocks into counties or other reasonable units. It is preloaded with information on the value of the property in each Census Block as well as income and population data. Economic losses in the flood model are built from actual geographical data extracted from Geographic Information System (GIS) maps. HAZUS contains a hydrologic model of the United States. This model builds on the U.S. Geologic Survey (USGS) EROS 30-meter digital elevation model, gauge records of water depths during floods, USGS regressions for ungauged reaches, and National Oceanic and Atmospheric Administration (NOAA) data, among others. Census data at the block level (e.g., square feet of residential property) are merged onto the geo-coded database. Guided by U.S. Department of Energy building characteristics survey data, the model estimates residence characteristics.

Starting from the NFIP loss database, HAZUS examines losses in known flood events, infers total losses by cost category (essentially residence and contents), then uses these to drive an engine for estimating losses by flood size. We estimated losses for 10, 50, 100, and 500 year floods (i.e., flood sizes with an annual probability of 10%, 2%, 1%, and 0.2%) in order to understand how damages and loss compensation differ across flood sizes and to estimate average annual losses.

The NFIP's market penetration rate in SFHAs is unknown because an enumeration of residences in SFHAs does not exist. Based on a property sampling, Dixon et al. (2006) estimates that penetration in SFHAs currently is 50 percent. Penetration may increase over time with NFIP marketing efforts or decrease due to increases in premium rates (FEMA 1999). Moreover, penetration in individual communities should vary widely from the mean. Therefore we ran HAZUS runs for penetration rates of 40 percent, 50 percent, and 60 percent, as well as with no flood insurance purchased.

We ran HAZUS simulations for the representative sample of 20 floodplains that were analyzed in other parts of the evaluation. The simulation examined the impact of flood mitigation requirements on savings on residential flood losses and the loss distribution among payers. The analysis explored the NFIP's financial impact, a central question about program effectiveness. Using simulation software, unlike using econometric analysis, permitted an analysis of the impact of flood mitigation on who pays for flood disasters and provided the flexibility to control for the size of the flood and its impact on flood assistance relief.

We used historical data on NFIP payouts per covered residence and on other federal and non-federal compensation of flood damages to estimate who would pay for the flood losses that HAZUS predicted. We systematically varied NFIP coverage levels to examine the effect of market penetration on costs by payer.

The HAZUS analyses estimate flood losses and flood-related tax write-offs per residence in SFHAs. We analyze how the results vary with insurance penetration level and estimate the damages prevented under 10, 50, 100, and 500 year floods (defined above), as well as for the blended risk of floods of all probabilities (frequencies) in an average year. The study also analyzes the increase in property values due to the existence of the NFIP. Moreover, we calculate the effects of flood risk, mitigation, and flood insurance coverage costs on property values for pre-FIRM and post-FIRM residences in SFHAs. The financial analysis estimates the flood-related cost that development in SFHAs imposes on taxpayers (due to flood disaster assistance, subsidized loans, and income tax write-offs of losses) as well as on owners and occupants of residences located in flood risk areas (either directly or through NFIP claims payments). The NFIP affects these costs by shifting some covered losses from taxpayers to policyholders and by requiring mitigation measures that may reduce flooding or reduce property damage when floods occur.[1]

In addition to the HAZUS analyses, we linked historical flood experience with data on bond ratings, government revenue and expenses, and employment levels. The data came from bond rating organizations and the Census of Governments. They powered a statistical regression analysis of the impacts of flooding on municipal finances and local economies, impacts that HAZUS was not designed to assess.

Distribution by Payer of the Costs of Floods

Excluding related wind damage, HAZUS estimates that annual expected flood costs for residences in SFHAs exceed $2 billion. This average cost masks huge variations between years. With 50-percent insurance penetration in SFHAs, flood cost to the federal government is estimated at $333 million, cost to state government at $16 million, and expected uncompensated losses to individuals at $771 million. Uncompensated losses are flood costs that individuals never recover through insurance or federal relief assistance.

Salient findings about the costs of flooding and who pays them on an annual per residence basis include:

- The average flood cost per residence in SFHAs is $290. The average flood cost per residence located below the BFE in SFHAs is $813 (averaged across residences below the BFE).
- The NFIP's expected outlay to the average residence located below the BFE is $381 with the NFIP subsidy paying $195 of these expenses.
- The average residence in a SFHA at or above the BFE annually costs taxpayers $48 in flood loss compensation. The average residence located below the BFE in SFHAs annually costs taxpayers $125.
- Average flood cost per residence in SFHAs is $4,131 in a 100-year flood. Average flood cost per residence located below the BFE in SFHAs is $12,511 in a 100-year flood. In a 100-year flood, taxpayers pay $865 of the costs for the average flooded residence in SFHAs and $2,621 of the costs for a residence below BFE.

Financial Impact of Floodplain Management by Payer

The impact of the NFIP on flood loss prevention through flood mitigation and insurance and its effect on who pays underscores the effectiveness of regulation in SFHAs. The HAZUS simulations show flood mitigation and insurance reduce total annual flood losses in SFHAs. For

[1] If the NFIP stimulated development in the SFHA post-FIRM, the cost per residence of that development to taxpayers would be no different than the cost per residence of other post-FIRM development in the SFHA.

example, for the average 50-percent flood insurance market penetration rate in SFHAs, the NFIP is estimated to reduce annual expected costs to the federal government by $527 million with $241 million due to insurance coverage of losses and $286 million due to mitigation. The NFIP also helps individuals by reducing uncompensated losses, flood costs that individuals never recover through insurance or federal relief assistance. At a 50-percent market penetration rate, this study estimates that the NFIP reduces annual uncompensated losses of individuals by almost $1.5 billion per year, with insurance payments contributing $712 million in reductions and mitigation contributing $770 million. The expected cost to the NFIP of discounts, or subsidies, to pre-FIRM residences is $457 million, almost half of total NFIP outlays. In the long run, these Congressionally mandated discounts represent a guaranteed NFIP operating deficit, built-in claims payments that should exceed the premiums collected. Between 1988 and Hurricane Katrina in 2005, the NFIP was able to borrow from loss reserves on its actuarially sound policies (money set aside to cover catastrophic losses like those from Hurricane Katrina) to cover the losses due to subsidies, allowing Congress to avoid funding the subsidies that it mandated. The costs to taxpayers given in this report exclude the costs of subsidies to pre-FIRM properties, which are presented as a separate cost element.

The NFIP's mitigation provisions reduce flood losses by one third, preventing an estimated $1.1 billion annually in losses to residences and their contents (the sum of the $286 million in avoided losses for the federal government and $771 million for individuals discussed in the previous paragraph, plus a $17 million reduction in state government costs). This HAZUS-based estimate agrees with the NFIP's estimate, based on loss experience, that $1 billion in flood damages are avoided each year as a result of the NFIP floodplain management regulations for new construction (FEMA. August 2002). The consistency of the two estimates buttresses the credibility of both estimation methods.

By breaking down the costs by payer, we were able to differentiate the effects of the NFIP on public expenditures and on the costs borne by people who own property in or live in SFHAs. The savings to the federal government and individuals that the NFIP has brought are substantial. As discussed previously, this study estimates that the NFIP has reduced the expected cost of flood-related government assistance to residences by $527 million, a 61 percent reduction under the most likely assumptions. The model estimates that the NFIP has decreased the costs of flooding to individuals who reside or own in SFHAs by $1.5 billion, a 67 percent reduction, with insurance penetration in SFHAs accounting for 50 percent of this reduction and mitigation measures accounting for the remainder.

As an example, the estimated impacts of mitigation and insurance on uncompensated losses after a 100-year flood are $1,520 and $1,306 reductions per residence, respectively, assuming 50 percent market penetration for flood insurance. This means that the Program reduces losses by an average of over $2,800 per residence after a 100-year flood. The associated reductions in federal government spending for the same level of flood are $817 per residence due to mitigation and $599 per residence due to insurance, or a total of $1,416. Because market penetration is unknown, varies by community, and can change over time, the study examines the difference in costs for the federal government under different market penetration rates. With 60 percent market penetration, federal spending would decline by an additional $115 per residence total. If market penetration is lower or drops to 40 percent due, for instance, to large premium increases, federal spending would increase by $123 per residence.

Clearly, the mitigation goal of the NFIP greatly reduces damages and costs to both the federal government and to individuals. Pre-FIRM residences that are located below the BFE are costly. Reducing their numbers over time seems a priority. FEMA's repetitive loss program efforts are a step in that direction. A reduced damage threshold for a substantial damage declaration and a closer tie of that declaration to the compensation process may merit consideration.

The HAZUS modeling offers insight into the long-debated question of whether the NFIP increases development in SFHAs. It estimates the impact of NFIP-induced mitigation on property values, which indirectly affect development in SFHAs.

NFIP mitigation requirements raise housing and infrastructure prices, forcing people to pay up front to reduce flood risk when they choose to build in a SFHA. That expenditure, however, reduces their ongoing cost of living in the SFHA. The expected annual flood-related cost of living in SFHAs without flood insurance drops from $321 per residence without mitigation to $213 with mitigation.

The common argument that the NFIP may have stimulated development and increased flood losses is not supported by our findings. While the NFIP may contribute to development by reducing the probability of catastrophic risk, the capitalized reduction in housing value due to expected flood losses over the lifetime of a 30-year mortgage loan at a 7 percent interest rate (the historic average) for a typical post-FIRM residence is only $1,651, less than one percent of the mean post-FIRM house value ($197,000). Without mitigation, the value reduction would be $2,488. The $837 increase in value for houses due to the NFIP's building standards represents the benefits of the mitigation measures built into the purchase price. These savings offset an unknown portion of the mitigation costs incurred in building the residences. Thus, while extensive development has occurred in SFHAs, the economic impact of flood hazard mitigation per new residence is small. These results deal with the average value of the uncompensated losses. The capitalized value increase due to mitigation requirements across all 3.1 million post-FIRM residences in SFHAs is $2.6 billion ($837 times 3.1 million). These estimates ignore the cost of mitigation, which offsets somewhat the savings achieved by reducing flood damages. The study does not measure any added value to individuals of the reduction in risk of catastrophic financial losses that results from spreading risk by purchasing actuarially sound flood insurance.

In contrast, the study indicates that the NFIP subsidy to pre-FIRM residences below BFE artificially inflates the value of these residences. The model estimates the capitalized reduction in property value due to flood losses under a historic 30-year mortgage loan for a typical insured subsidized pre-FIRM residence below BFE is $16,010. Without the subsidy, the capitalized value reduction would be $40,030. Thus, in a fully informed housing market, the subsidy would raise the value of the average pre-FIRM residence by $24,020. Thus, the subsidy has contributed to maintaining market demand for pre-FIRM residences located below BFE and discouraged rebuilding that would have raised elevations above BFE. That means the subsidy provides an incentive for retaining pre-FIRM residences rather than replacing them, essentially an incentive against redevelopment.

Both increasing flood insurance market penetration and NFIP-induced mitigation reduce government spending to compensate flood losses. At the same time, if the housing market is rational and well-informed, the NFIP does not raise property values enough to spur development. Thus increased flood insurance penetration in SFHAs seems desirable.

Financial Impact of Floods by Income Group

The next part of the study focuses on the effects by income group. Combining Census data on incomes and other demographics with HAZUS simulations showing which blocks would be inundated in a 100-year flood supports regression analysis on the characteristics of SFHA residents. The regression reveals that two divergent groups are significantly more likely to live in an SFHA. First, the block-level income data show a higher proportion of households in higher income brackets own residences in high flood risk areas near coastlines and lakes, possibly drawn by the aesthetics of living or vacationing near the beach or of having a water view. From a housing affordability viewpoint, these homeowners can afford the premium from flood insurance. Second, the modeling results indicate that low income households typically live in higher risk areas than middle income households, possibly because they sometimes must take large risks to get affordable housing, choosing homes that are both old and floodprone. Because they often live in the SFHA and their residences are disproportionately often pre-FIRM and therefore may not be elevated above the BFE, renters typically suffer higher flood damages than homeowners in floods of comparable size.

Controlling for housing value, households living in extreme poverty (with incomes less than $10,000) have significantly lower flood damages than middle class households with incomes between $30,000 and $75,000. Conversely, the majority of the population living in poverty (household income between $10,000 and $20,000) has significantly more flood damages than middle class households with incomes between $30,000 and $75,000. Low income households above the poverty rate (income between $20,000 and $30,000) also have significantly larger flood losses than middle income families (income between $30,000 and $75,000). This is a public policy issue because, having lower incomes and often less earning power, low-income households are less likely than households with higher incomes to be able recover from the economic losses that result from a flood.

The policy implication is that floodplain management and emergency management planning efforts need to reach larger parts of the population, somehow reaching into pre-FIRM areas where many of the residents are renting. Much of the low income population's capital lies in their possessions, most strongly so if they own their home[2]. When a low income person loses a home, the loss tends to be catastrophic.

The Impact of Flood Losses on Communities

Subsequent sections of this report look beyond the NFIP and examine the impact more generally on local economics and local government finances of all flood events that caused property damage across the US in a two year period. Flood events were estimated to significantly decrease employment in communities by an average of 3.4 percent. Unemployment benefits presumably will increase as employment falls, and many floods will bring federal relief. The average increase in personal transfers due to a flood is 3 percent. Despite these transfers,

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[2] See data from the Department of Housing and Urban Development at http://www.huduser.org/publications/HOMEOWN/WAccuNHomeOwn.html, as of 08/2006.

disrupted employment and income should reduce the wealth of affected residences and businesses. Employment levels, however, recovered after one year.

Actual flood events cause affected municipalities to curtail expenses and incur more debt, at least in the year of the flood and the following year. Presumably the debt increase is needed to pay for flood costs and make up for lost tax revenues. Local governments thus spread some flood recovery costs across years through future taxes on local residents. Municipalities with no floods within the past two years but at high risk of flooding, as measured by a high average premium for policies in force, have lower outstanding debt than municipalities at lower risk.

In the year of a flood, Federal transfers decline by 29 percent and state transfers by 34 percent, resulting in a $97 million revenue decline. This may happen because service delivery that generates state revenues is disrupted after the flood or because local government involvement in post-flood activities during the year a flood occurs consumes resources normally used for writing grant applications. Conversely, the year after a flood, federal transfers rise significantly, with the local government recouping the $6 million in federal transfer payments that it lost the previous year (from the coefficient of flooded last year in the federal transfer equation). State revenues only partially recover in the year following the flood, however, remaining almost $30 million (11 percent) below pre-flood levels, but this difference only is significant at the 85% confidence level.

Flood events, by placing stress on municipal finances, also can affect municipal bond ratings. Indeed, flood events are correlated with lower average municipal bond ratings after a flood than before (at a 90 percent confidence level).

Conclusions and Recommendations

This study confirms that the insurance and floodplain management elements of the NFIP reduce costs to government and individuals and prevent uncompensated losses. It finds that the NFIP mitigation requirements prevent substantial costs to households and government in the aggregate. The common argument that the NFIP may have stimulated development and increased flood losses is not supported by our findings. The study is limited in that on the one hand it did not evaluate the costs of mitigation in housing construction, but on the other hand it also did not include the considerable social and non-economic costs of floods and disrupted lives, exposed clearly in the wake of the 2005 flood events. Other research confirms the strong value of mitigation projects generally,[3] showing mitigation costs will be less than the flood losses that HAZUS suggests will be averted.

In terms of the insurance component of the NFIP, insurance coverage modestly reduces costs to government and considerably reduces uncompensated flood losses to individuals. These findings emphasize the desirability of high insurance penetration within the SFHA. This study also indicates that although the NFIP may not provide a strong economic incentive to develop in the floodplain, its subsidy for older residences below BFE probably discourages redevelopment of the residences most at risk of flood losses. Insurance coverage adds so little to property values due to the average value of the reduction in uncompensated losses that it is not plausible to think it creates considerable development pressure. The subsidy of pre-FIRM properties through

[3] Research indicates that the benefits return on investment in such flood mitigation projects is four dollars for every dollar spent (Multihazard Mitigation Council, 2005, p. 149)

discounted insurance premiums, however, is likely to have slowed rebuilding of this housing stock above BFE. Rebuilding would yield significant mitigation cost savings from the government's perspective.

Flooding affects communities more broadly than HAZUS is able to measure. Flood impacts not captured in HAZUS include that bond ratings fall, raising the cost of municipal borrowing, employment declines for one year, municipal spending declines, and municipal debt rises. Further, our study and HAZUS both "ignore impacts on people including lives lost and people displaced, family trauma and social disruption, loss of items like family photos that cannot be replaced, business interruptions, disruption of government services, tourism reductions, and shortages of critical human services. Indirect environmental costs also can arise, e.g., the costs if a sewer line breaks polluting a bay, or the loss of an erosion-buffering beach or wetland that may alter the future vulnerability of the community." (David et al. 1999). Thus the costs analyzed in HAZUS are merely the most readily measurable subset of the total costs of flooding.

Because the costliest part of this study was design and model development, follow-up research building on the existing design would be more affordable and should be undertaken. When the 2010 Census is released, its structure inventory should be loaded into HAZUS, along with other updates, and our analysis should be updated. The update should reassess the annual cost savings resulting from flood insurance and related mitigation efforts, savings to government, and the impact on development costs in the SFHA.

We also recommend experimenting with a further set of HAZUS estimates that it may be appropriate to run annually in order to better document and publicize the savings to society and to government that result from NFIP-induced mitigation and from flood insurance sales. These estimates would cover all floods that were declared as disasters during the year, plus any other floods above a selected size or damage threshold that were not confined to sparsely populated areas.[4]

[4] An initial simulation would produce a damage estimate that should resemble actual damages, allowing verification that the model reproduced reality reasonably well. Estimate quality probably will be better across the portfolio of the year's floods than it is for any individual flood. Additional simulations should be run to estimate what damages and government costs would have been if no NFIP-induced mitigation had occurred and if flood insurance penetration had differed from actuality.

1. INTRODUCTION

On average, floods in the United States caused about $6 billion in damages annually between 1955 and 1999 including damages to private buildings, public facilities, and agriculture (University of Colorado 2001). However, standard homeowner policies do not include flood coverage, as private insurers historically have found it unprofitable to insure low-frequency, high-severity disasters such as floods. Until the establishment of the National Flood Insurance Program (NFIP) in 1968, the primary recourse for flood victims was federal government disaster assistance (FEMA, 2002, p.1). Congress adopted the NFIP in response to the ongoing unavailability of private insurance and continued increases in federal disaster assistance in order to provide federal flood insurance protection as well as to give local governments an incentive to adopt floodplain management regulations to mitigate losses from flooding in special flood hazard areas (SFHAs). The floodplain management regulations require newly constructed residences to be elevated above the base flood elevation (BFE) and nonresidential buildings to be elevated above or floodproofed (made watertight) to that elevation. These regulations apply to structures that were constructed or substantially improved after December 31, 1974, or after the effective date of the initial Flood Insurance Rate Map (FIRM) of a community, whichever is later.

Congress enticed communities to join the Program by offering affordable insurance rates in exchange for adoption of stricter ordinances and building standards for future construction. Discounted flood insurance policies were needed to enroll and retain those residents whose buildings had already, law-abidingly, been constructed in floodplains and that were built at elevations substantially below the BFE. These pre-FIRM structures are not subject to floodplain management regulations unless they were repaired after substantial damage or were substantially improved post-FIRM. The NFIP charges actuarial rates to post-FIRM structures, discounted premiums, generally referred to as “subsidized,” to pre-FIRM structures built below BFE, and actuarial rates to pre-FIRM structures built above BFE.

The purposes of this study are to examine (1) the impacts that the NFIP (i.e., flood insurance and the elevation requirement.) has had on the costs of flooding and their distribution among payers; and (2) how well the NFIP serves low-income households and communities. The first purpose probes the NFIP’s financial impact, a centerpiece question about program effectiveness. The second purpose explores the program’s adequacy for the disadvantaged population, a key measure of program equity. Moreover, this study examines the consequences of flood hazards on municipal revenues and expenses, as well as the impact on local economic activity (employment) and bond ratings.

To evaluate flood costs by payer, this study incorporates the institutional and economic framework of flood relief compensation for different simulated flood levels as an add-on module to the recently developed Hazards U.S. Multi-Hazard (HAZUS-MH) flood loss simulation model.[5] The add-on modules break down the cost estimates by payer, yielding:

- Costs to flood victims
- Federal disaster relief costs
- Costs to taxpayers

[5] See www. http://www.fema.gov/hazus/ab_main.shtm

- Costs to the NFIP

In addition to the breakdown of the cost estimates by payer, this study evaluates the financial impact of the NFIP on SFHAs. To estimate the savings per payer from the NFIP mitigation standard, this study simulates flood losses under two scenarios. The first scenario captures flood losses under NFIP floodplain management requirements (notably the elevation requirement) and current levels of flood insurance penetration. The NFIP requires new structures to be built at or above the BFE, which reduces the probability of flood damages in structures to a frequency of less than one percent per year. The second scenario simulates flood losses in the absence of floodplain management.[6] The simulation decomposes the flood losses between payers and calculates the savings per payer from the NFIP mitigation standard.

Simulation analysis of the NFIP mitigation standard using HAZUS shows (1) the impact of floodplain management on who pays for flood disasters (controlling for the size of the flood); (2) the cost that residences in SFHAs impose on society; (3) the relationship between flood mitigation, flood insurance penetration, and flood assistance relief; and (4) the capitalized value of floodplain management on property values, with its indirect consequences on development in SFHAs. The results address several policy questions that include whether the NFIP is effective, how the NFIP has affected development, and challenges faced by the NFIP in the future.

In addition to analysis of the NFIP impact per payer, this study evaluates the distribution of flood damages by income group in SFHAs, a key measure of program equity. The poor and the disadvantaged population tend to live in older housing built before the NFIP mitigation requirements took effect, meaning a flood will cause more damages in their homes than in newer homes. Moreover, their assets are disproportionately the clothing and furnishings in their home (and sometimes their home itself), things that largely must be left behind in an evacuation. They lack the financial means to recover from a flood.

HAZUS offers the potential to match flood losses at the Census Block with demographic and economic data of the population in each Census Block. This provides a refined data set to examine the relationship between poverty, income, race, urbanization, and flood losses. In the analysis, we use HAZUS to simulate a water overflow of a 100-year flood, which results in the inundation of various Census Blocks. From the resultant flood levels in each Census Block, we determine whether damages inflicted on residences are different across income groups, including those living under poverty. The analysis reveals two interesting results. First, households in the highest income brackets may be more prone to live in higher flood hazard areas because of the esthetic attributes of living next to water, and they can afford the premium from flood insurance. Second, low income households live in higher risk areas than middle income households because they sometimes must live in those hazardous areas in order to afford housing. Furthermore, after factoring out income, the analysis also estimates the impact of urbanization, race, and number of rental units on flood damages at the Census Block level.

A shortcoming of our financial analysis of floods is that HAZUS does not capture impacts on such financial outcomes as bond ratings and local government finances. The HAZUS

[6] The analysis does not include damages (compensation) to agriculture, transportation systems, highways, and bridges, which insurance and mitigation under the NFIP does not generally address. Moreover, the analysis primarily focuses on damages to flood-exposed residences, which are the segment of the population most adversely affected by flooding.

analysis also does not capture the effects of floods in relation to the local municipal economy. Our study uses other data to estimate the financial effects of floods on local government finances, bond ratings, employment and personal transfers. The results underscore the extensive damages that floods cause beyond residential flood damages.

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2. BACKGROUND

2.1. National Flood Insurance Program

Devastating natural disasters for communities include earthquakes, tornados, floods, and fires. The effects of flooding differ from other disasters in terms of their probability distribution, the nature of the damage caused, and the precautionary measures that could be taken. Among natural disasters, size and frequency make floods the major source of financial stress to governments and individuals in the United States. Although the importance of the federal role in flood protection was recognized at the turn of the 20th century, the prevailing view was that technological advances would prevent the effects of flooding. This view changed in the late 1950s, and the need to manage flood prone lands was recognized.

In 1966, President Johnson submitted to Congress the study "Insurance and Other Programs for Financial Assistance to Flood Victims." The study concluded that federal flood insurance was feasible and would promote the public interest. The National Flood Insurance Act (Title XII of the Housing and Urban Development Act of 1968) created the National Flood Insurance Program (NFIP). However, participation in the NFIP did not become widespread until the Flood Protection Act of 1973 that made community participation in the NFIP a condition of eligibility for certain types of federal assistance. The NFIP objectives were twofold: (1) constraining the cost of damage caused by flooding, and (2) providing economically feasible relief to victims through insurance.

The NFIP delegates to local governments the enforcement of national guidelines that require new houses and other buildings in SFHAs to be protected against a one percent annual chance flood. Briefly, these guidelines require post-FIRM residences to be built at or above the base flood elevation (BFE), which reduces the probability of flood damages in structures to a frequency event of less than one percent per year. Non-residences must be elevated to the BFE or floodproofed (made watertight) to that elevation. A structure is post-FIRM if it was constructed or substantially improved after December 31, 1974, or after the effective date of the initial Flood Insurance Rate Map (FIRM) of a community, whichever is later. Pre-FIRM structures were not subject to floodplain management regulations unless they are substantially improved or substantially damaged. The NFIP charges actuarial rates to post-FIRM structures and subsidizes premiums of pre-FIRM structures.[7]

Communities are likewise accountable for compliance under the Flood Disaster Protection Act of 1973, which provides statutory and financial incentives to communities to participate in the NFIP. For example, participation in the NFIP is a necessary condition for eligibility for some forms of federal assistance under a disaster declaration. Stimulus for compliance with the elevation requirement thus stems directly from regulation on issuance of new building permits and indirectly from the flood insurance risk premium (Kunreuther, 1996). This NFIP approach to flood mitigation, as a result, is primarily nonstructural (Pasterick, 1998).

In the academic literature, Browne and Hoyt (2000) and Kriesel and Landry (2004) analyzed statistical correlations between federal relief costs, community participation in the NFIP, and insurance penetration. A shortcoming from these econometric analyses, however, is

[7] Pre-FIRM structures pay a flat rate per dollar of insurance coverage. Low risk pre-FIRM structures may choose to pay actuarial rates if lower than the subsidized flat rate.

that the assistance relief depends on the level of insurance penetration and vice versa. Perhaps, more importantly, time series econometric analysis cannot reliably separate savings from the NFIP mitigation standard from other factors that explain flood losses in SFHAs.

2.2. Previous Studies

As Scanlon (1988) has observed, "…while it is obvious disasters are negative events causing injury and death, damage, and destruction, macro-economic studies show little long-term economic effects from disaster. That is because disasters create both losers and winners, and these balance out. Who loses and who wins is not random but a result of public policy decisions. The losers include individuals who are injured, lose their jobs, lose their homes, lose a wage earner, or lose a place of residence. The winners include individuals who earn extra money because they are involved in emergency response or restoration." Increasingly, good politics dictates helping all disaster-stricken communities to emerge as winners from a federal assistance viewpoint.

Extensive work has been done defining the categories of costs that result from disasters and agreeing on ways to estimate them through case studies. The guidelines are described in three documents:

- "The Impacts of Natural Disasters: A Framework for Loss Estimation," from the Committee on Coastal Erosion Zone Management of the National Research Council (1999).
- "The Hidden Costs of Coastal Hazards: Implications for Risk Assessment and Mitigation," which is a panel report from the H. John Heinz III Center for Science, Economics and the Environment (2000).
- An article derived from the Heinz Center report, "Uncovering the Hidden Costs of Coastal Hazards" (David et al. 1999).

These papers establish three categories of impacts, which the Heinz Center report (p. 173) defines as follows:

- Primary impacts – "The damage and losses that can be directly attributed to the storm itself; examples include injuries and loss of life, damage to property and infrastructure, and losses of natural habitats or fish and wildlife populations."
- Secondary impacts – "Those that occur over time; examples of indirect impacts on people include family trauma and social disruption, business interruptions, [disruption of government services, tourism reductions,] and shortages of critical human services. With respect to indirect environmental effects, [a sewer line could break polluting a bay,] fish and wildlife populations may be slow to recover, and the loss of an erosion-buffering beach or wetland may alter the future vulnerability of the community." The indirect social and environmental losses constitute "hidden costs" that typically are hard to measure and value.

- Offsetting benefits – Gains associated with disaster recovery such as a construction industry boom and associated job opportunities, rental housing for temporary workers, and retail food sales.[8]

In addition, costs arise in administering and implementing mitigation efforts and providing disaster relief.

The recently developed Hazards U.S. Multi-Hazard (HAZUS-MH) flood loss simulation model is a simulation model that estimates direct economic losses (building and contents losses), as well as indirect losses (relocation losses, wage losses, rental income losses) for varied types of flooding. The level of aggregation in HAZUS is at the Census Block, i.e., flood losses are calculated at the mean characteristics of the Census Block. In addition to the flood loss at each Census Block, we have information on the mean value of the property at each Census Block as well as income and population data. Analysis of the NFIP's financial impact may use damage curves in HAZUS for different structural flood elevations. The NFIP covers flood losses to buildings and contents, but it does not protect against the indirect costs of flooding (e.g., temporary housing) to residences.[9]

Economic losses in the flood model are built from actual geographical data extracted from Geographic Information System (GIS) maps. HAZUS contains a hydrologic model of the United States. This model builds on the U.S. Geologic Survey (USGS) EROS 30-meter digital elevation model, gauge records, USGS regressions for ungauged reaches, National Oceanic and Atmospheric Administration (NOAA) data, and the hydrologic derivatives. Census data at the block level are merged onto the geo-coded database. Guided by U.S. Department of Energy building characteristics survey data, structure characteristics are estimated. The HAZUS data file contains square feet of residential property by block. Starting from the NFIP loss database, the model examines losses in known flood events, infers total losses by cost category (essentially structure and contents), then uses these to drive an engine for estimating losses by flood size. HAZUS stores most data at the Census Block level, with the ability to aggregate blocks into counties or other reasonable units.

2.3. Costs and Consequences of Floods

A time series analysis by the National Weather Service (Pielke et al. 2002) yielded some insight on the costs and consequences of floods by analyzing a 60-year series of the federal government's annual estimates of the costs of flooding, with the number of communities participating in the NFIP included as an explanatory variable. Federal flood disaster costs dropped significantly as NFIP participation rose. Beyond this, our knowledge of costs and consequences largely comes from case studies (e.g., FEMA 2000, H. John Heinz III Center 2000, Gruntfest 1995).

Unfortunately, existing case studies (e.g., Philippi 1994) do not yield a representative picture of the situation nationally. Indeed, the range of mitigation approaches, flood sizes, warnings of flood arrival, flood insurance penetration, community characteristics, and recovery options probably is too diverse to credibly cover through case studies. Consequently, case study results are hard to generalize and the legitimate reasons that case study findings vary are hard to

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[8] These offsetting benefits may also have offsetting costs.

[9] The study does not address the offsetting benefits.

pinpoint. Exacerbating this problem, existing case studies almost all focus on spectacular disasters. Nevertheless, when one goes beyond hard financial losses to social and environmental costs, case studies may be the only practical research approach. At a national level with claims data, FEMA currently estimates $1.1 billion annual cost savings from the NFIP's flood mitigation requirements. Yet, no breakdown exists of the cost and NFIP impact to uncompensated losses and government from floods. The effectiveness of the NFIP for different flood levels is also unknown.

Knowledge of low-income issues is also spotty. Repeated flooding resulting from hurricanes striking North Carolina has raised concerns that vulnerable low-income communities have virtually no coverage. This issue has been covered in the popular press but has received only modest attention in the academic literature. Browne and Hoyt (2000) found that lower income reduces the probability of buying flood insurance. They concluded that a mechanism is needed to help low-income households get the flood insurance they need. They recommended a voucher system. The Federal Emergency Management Agency (FEMA) has Group Flood Insurance Policies for low-income people, which are sometimes issued, for example, following a flood in low-income areas. These are three-year policies paid for using disaster assistance funds in exchange for the policyholders' agreement that they will purchase the insurance themselves thereafter. However, the FEMA Inspector General found the actual renewal rate post-subsidy has been less than 10 percent.

2.4. Organization of the Report

This study addresses several policy questions that include what are the costs and consequences of flooding including the impact on local governments and local economies, whether the NFIP is effective at reducing the costs of floods and the share of those costs borne by government, how the NFIP has impacted development and different income groups, and challenges faced by the NFIP in the future. Moreover, we evaluate two central objectives of the NFIP: (1) constraining the cost of damage caused by flooding, and (2) providing economically feasible relief to victims through insurance. We also evaluate differences in damages inflicted to residences across ethnic and income groups, including those living under poverty. The analysis also yields insight into the continuing debate about the NFIP's impact on development.

Section 4 presents the methodology used in the study to calculate the distribution of payers for flood losses and the NFIP's impact by payer. The section describes the modules we added to the HAZUS model that decompose who pays for losses from floods of different sizes. These modules break down the NFIP's impact on uncompensated losses and insurance claims for individuals as well as government losses. Uncompensated losses are flood costs that individuals never recover by insurance or federal relief assistance.

To evaluate flood costs by payer and the financial impact of the NFIP on SFHAs, Section 5 simulates losses under two scenarios. The first scenario captures flood losses under NFIP floodplain management guidelines (the elevation requirement) and current levels of flood insurance penetration. The second scenario simulates flood losses in the absence of floodplain management. The simulation decomposes the flood losses between payers and calculates the savings per payer from the NFIP mitigation standard. For this decomposition, we use our add-on modules (discussed in section 3) that break down HAZUS cost estimate by payer. To estimate the impact on SFHAs, the simulation applies national data on the distribution of elevations of structures in SFHAs with the damage curves embedded in the HAZUS-HM flood loss simulation model. Section 6 shows simulation results. The analysis addresses several policy questions that include whether the NFIP is effective, how the NFIP has impacted development, and challenges faced by the NFIP in the future. Section 6 also discusses implications of the results.

Section 7 estimates the flood losses of lower income households in SFHAs. This section uses HAZUS generated data to examine the relationship between poverty, income, race, urbanization, and flood losses. We determine whether damages to residences are different across income groups, including those living in poverty. The analysis also estimates the impact of urbanization and number of rental units on flood damages at the Census Block level.

Section 8 addresses limitations in the financial analysis of floods with HAZUS and fills gaps. The section compiles a list of the outcomes/impacts for analysis and the data sources containing the outcome data. It then applies the data to determine the financial effects of floods on local government finances, bond ratings, change in employment, and personal transfers. The results underscore the extent of the damages of floods beyond residential flood damages.

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3. PAYER DISTRIBUTION OF THE FINANCIAL IMPACT OF FLOODS

To evaluate flood costs per payer, this study incorporates the institutional and economic framework of flood relief compensation for different simulated flood levels as add-on modules to HAZUS. The modules break down the NFIP's impact on uncompensated losses and insurance claims for individuals as well as government losses. Uncompensated losses are flood costs that individuals never recover by insurance or federal relief assistance.

Here, we describe modules added to the HAZUS model that decompose who pays for losses from floods of different sizes. Section 4.1 describes programs of flood relief compensation; and section 4.2 describes how programs of flood relief compensated losses from the Great Flood of 1993. Section 4.3 describes a flood assistance reaction function that defines modules we added to HAZUS. The reaction function models government response to flood losses and it uses parameterizations based on The Robert T. Stafford *Disaster Relief and Emergency Assistance Act*, Public Law 93-288 limits and historical averages in the federal response to flood disasters.[10]

3.1. Federal Flood Assistance Relief

The presence of government intervention in the prevention and compensation for damages from natural hazards is well documented. For example, the literature describes market distortions from federal assistance relief (Dacy and Kunreuther, 1969; Kaplow, 1999) and insurance subsidies (Goodwin and Smith, 1995). Yet, no comprehensive breakdown exists of the cost to individuals and government from natural disasters.

3.1.1. Federal Emergency Assistance and Limits

Under an emergency declaration, federal support is available to assist state and local flood relief efforts. The federal share for emergency assistance is 75 percent of the eligible costs and, in general, total assistance provided for a single emergency cannot exceed $5,000,000, unless the President determines that continued emergency assistance is immediately required. The extent and nature of the federal assistance under a major disaster area is notably larger than in emergency areas, with Congress sometimes appropriating billions of dollars to assist in a single disaster.

3.1.2. Individual Assistance Programs after a Disaster Declaration

Under the Stafford Act, a disaster declaration triggers federal aid to victims in the form of loans, grants, and tax breaks. Individuals may qualify for Small Business Administration (SBA) loans (i.e., federally subsidized loans) to repair and replace homes and property that sustain damages not covered by insurance. SBA loans had a 4.5 percent annual interest rate in mid-2004 (lower than market mortgage rates). The rate matches the Federal Fund Rate (the prime rate), which fluctuates with monetary policy. SBA loans are capped at $200,000 to repair damaged homes and at $40,000 for replacement of personal property damaged in a declared disaster. Most SBA loan applications following floods are rejected, as the SBA does not find the applicants creditworthy (Sharing the Challenge, 1994).

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[10] One caveat is that any parameterization of a reaction function requires some simplifying assumptions derived from historical records that are only an approximation of actual response.

In case the individual fails to qualify for a SBA loan, the individual may qualify for individual assistance grants under the Individuals and Household Program (IHP). IHP grants provide money and services to cover individuals' losses that the victims are unable to pay through other means (e.g., insurance, loans). Basic assistance (e.g., temporary housing) under the individual assistance program cannot discriminate based on income or other residential characteristics (e.g., level of flood insurance, renter vs. owner) or individual characteristics (e.g., whether the individual qualified for a SBA loan, income).

Shares and limits on federal assistance under the IHP are defined by the Stafford Act. This Act states that no individual or household shall receive financial assistance greater than $25,000 (year base 2000)[11] with respect to a single major disaster. There are two types of grants: direct grants to individuals (up to $15,000) and assistance to individuals through grants to the state (up to $10,000). The federal government pays for 100 percent of the costs of direct grants, and the state matches 25 percent of the cost of assistance to individuals through grants to the state. Historically, average grants approved for individual assistance ranged from $2,000 to $4,000 (Bea 1997).

To provide further relief to individuals in disaster areas, losses not covered by insurance or other reimbursements that exceed 10 percent of the disaster victim's annual income are deductible from federal income taxes. Tax deductions may impose some stress on government finances because of losses in tax revenues.

3.1.3. Assistance Programs to Businesses and Other Non-Residential Properties after a Major Disaster Declaration

Similar to the assistance relief to residences, in the event of a disaster declaration, non-residences may qualify for SBA loans to repair and replace property that sustained damages not covered by insurance. A maximum SBA loan of $1.5 million is available for a business that suffered disaster losses to its property, equipment, or through a loss of income known as economic injury. Business properties are also entitled to casualty loss deductions, and these losses may be treated as business expenses. Unlike individual applicants, non-residences, such as businesses, are not entitled to federal grants under the IHP.

3.1.4. Other Assistance Programs

Other forms of federal assistance under a disaster declaration include acquisition or relocation of property located in high-hazard areas, elevation of flood-prone structures, and dry flood-proofing activities to bring structures into compliance with minimum NFIP requirements. Regardless of NFIP participation, Federal relief also includes public assistance for repair or replacement of public facilities and infrastructure that are damaged or destroyed by the disaster. For insurable structures, the assistance from FEMA is reduced by the amount of the insurance settlement.

[11] This amount is adjusted annually to reflect changes in the Consumer Price Index for All Urban Consumers published by the Department of Labor.

3.1.5. A Description of NFIP Assistance

A main source of relief for flood losses is insurance provided by the NFIP. In May 2006, more than 5 million policies were in force representing more than $900 billion of coverage. Of these policies, 3.1 million are in Special Flood Hazard Areas (SFHAs).

Flood insurance for residences has a $250,000 ceiling of coverage for homes (and $100,000 for contents), whereas for non-residences, coverage is up to $500,000 (and $500,000 for contents). Because contents coverage is separate, renters also can be covered by flood insurance. Basement upgrades are not covered by flood insurance. Currently, the average flood insurance premium costs approximately $425 a year for an average coverage of $120,000 for residences, whereas for nonresidences, the average premium is $1,275 for an average insurance coverage of $218,000, exclusive of coverage for contents. The NFIP, moreover, insures only damages to buildings and contents (e.g., it does not insure indirect costs of flooding such as wage loss). Dixon et al. (2006) in the RAND Corporation sub-study of the evaluation find that the average insurance penetration in SFHAs is 50 percent.

3.2. Who Pays for Flood Relief? The Great Flood of 1993

The Great Flood of 1993 was exceptional in American history because of the extent of devastation both to individuals and to industry in the American heartland with the largest financial effect of any natural disaster in America before 2004. Damages totaled over $10 billion, 50 people died, hundreds of levees failed, and thousands of people were evacuated - some for months and some never to return to their homes. The flood was unusual in the magnitude of the crests, the number of record crests, the large area impacted, and the length of the time the flood was an issue. At least 15 million acres of farmland were inundated, some of which were expected to be unusable for years to come.

In 1994, the Clinton Administration's Flood Plain Management Task Force created a committee to investigate the causes and consequences of this flood catastrophe. The Committee's report, *Sharing the Challenge: Floodplain Management into the 21st Century* (Galloway, 1994), was issued the following year. This report analyzed levels of federal relief and federal insurance compensation across all programs in the Midwest flood zone. Tables 1 and 2, drawn from the Committee report, reveal who paid for the losses caused by the 1993 Midwest Flood. Table 1 shows estimated flood damage and FEMA expenses per state.

Table 1 shows that overall flood damages (first column) totaled almost $11.7 billion. Of this total, about 38 percent was non-agricultural (third column) losses to individuals and non-agricultural businesses. FEMA payments were about one-quarter of the estimated non-agricultural damages of $4.475 billion.

Table 2 analyzes the NFIP's contribution to the overall federal flood relief response. Table 2 shows that a combination of federal SBA loans, public assistance relief (cleanup and public service recovery) and individual assistance (including temporary housing) constituted about 86 percent of federal compensation to flood victims. NFIP payments represented about 14 percent of the total federal flood relief response. FEMA assistance to individuals represented $449 million out of the $1.141 billion FEMA paid out for Midwest Flood victims, or about 40 percent. Market penetration in the Midwest in 1993, however, was far below the current 50% estimate. Penetration was lower for several reasons. First, the National Flood Insurance Reform

Act of 1994 greatly improved compliance with the mandatory purchase requirement. Second most of the neighborhoods flooded were older, low to moderate income neighborhoods. There is very little mortgage activity in these areas and not much to generate mandatory purchase (see Galloway, 2006).

TABLE 1. Total Flood Damages and Federal Flood Relief, the Midwest Flood of 1993 (in millions)

State	Total Flood Damage	Agricultural Damage Estimates*	Non-Ag Damage Estimates	Total FEMA payments
Illinois	$1,535	$605	$930	$254
Minnesota	1,023	800	223	75
Wisconsin	909	800	109	67
Iowa	2,200	1,200	1,000	251
Kansas	574	434	140	98
Missouri	3,000	1,800	1,200	266
Nebraska	347	292	55	61
South Dakota	1,500	705	795	33
North Dakota	595	572	23	36
Total	**$11,683**	**$7,208**	**$4,475**	**$1,141**

*Agricultural damages stem from crop losses and compensation comes from agricultural emergency programs.
SOURCE: FEMA. 2002. The 1993 Great Midwest Flood: Voices 10 Years Later. Washington, DC: FEMA.

TABLE 2. Federal Relief after the Great Midwest Flood of 1993

Type of Relief	Amount (in millions)	Percent of Total Federal Relief
SBA Loans	$ 597	34
FEMA Individual Assistance (incl. Temporary Housing Assistance)	449	26
FEMA Public Assistance	455	26
NFIP Payments	238	14
Total	$1,739	100

SOURCE: Executive Office of the President. 1994. Sharing the Challenge: Floodplain Management into the 21st Century. Washington D.C.

The next section describes assumptions needed to break down the direct costs among payers, factoring in how the extent of damage affects the payer distribution.

3.3. Modules that Compute the Distribution of Payers: Empirically Based Assumptions

Flood insurance covers flood losses to buildings and contents, but it does not protect against the indirect costs of flooding. The latter include possible losses due to temporary housing and income/wage loss among many others. In the calculation of expected flood loss, HAZUS reports both direct and indirect damages to residences. The NFIP compensates direct costs, while federal relief for uninsured losses may compensate both direct and indirect losses. Conceptually, federal relief is best justified when designed to compensate losses from risk that is not insurable or affordable to the population. Still, by the Stafford Act, specific types of assistance (e.g., temporary residence) under a disaster declared area cannot discriminate on the basis of individual (e.g. income) or residential (e.g., level of flood insurance) characteristics.

NFIP payments for insurance claims that stem from actuarially-rated (generally, post-FIRM) policies are not treated as a cost to the government because premiums pay for these losses. In contrast, the rate discount (or subsidy) provided by the NFIP to pre-FIRM structures is a direct cost to the program in the accounting of the payers for flood losses. This subsidy increases financial risk to the NFIP and constrains the program's flexibility to achieve some of its goals, e.g., better mitigate the costs of flooding. That is, monetary losses to support the subsidy have opportunity costs that can be used alternatively to better achieve the NFIP objectives. Between 1988 and Hurricane Katrina in 2005, the NFIP was able to borrow from loss reserves on its actuarially sound policies (money set aside to cover catastrophic losses like Katrina) to cover the losses due to subsidies, allowing Congress to avoid funding the subsidies it mandated. The General Accounting Office reports that 29 percent of the current policyholders are paying subsidized pre-FIRM rates[12] and the premium of pre-FIRM structures is 40 percent of the unsubsidized price.[13] In the flood assistance response function, the subsidy program thus accounts for losses equaling (100 percent-40 percent) x average NFIP loss per subsidized pre-FIRM structure x 0.29 of the number of all insured structures.[14]

An additional source of relief to flood losses in a declared disaster area is federal relief in the form of grants and subsidized loans. Small Business Administration (SBA) loans are available to help finance uninsured repairs to residences and non-residences. Although compensation through SBA loans provides temporary relief, it also increases the cost to victims of the disaster in the form of interest payments. The interest rate for a 20-year loan was 4.5 percent as of late 2005:[15] this rate is tied to the federal prime rate. To determine damages to residences paid with SBA loans, this report assumes that loans are acquired consistently with the average debt to income ratio held by U.S. households of 150 percent. That is, in the simulation, 75 percent of uncompensated property losses are paid with SBA loans for those who qualify.[16] (Given the long-term nature of SBA loans, the minimum SBA loan in the analysis is $2,000). To determine what percentage of those applying for SBA loans qualify, we use data from *Sharing the Challenge* (1994) that reports 30 percent acceptance rates for SBA loan applications. Therefore, the simulated level of SBA loans in these modules is the product of uncompensated losses, percent of loan requested (75%), and acceptance rates (30%).

To determine individual assistance grants, we use the average value of IHP grants in declared flood disaster areas from historical records ($2,500). To determine who qualifies, the simulation uses the percentage that did not qualify for SBA loans (conditional on damages larger than $2,000) and multiplies this percentage by the acceptance rates for IHP grants (64 percent).

[12] In 2006, the percentage of pre-FIRM policies fell to 24 policies as NFIP market penetration increased.
[13] See GAO. Flood Insurance. Challenges Facing the National Flood Insurance Program (2003) located at http://www.gao.gov/new.items/d03606t.pdf.
[14] It is unclear how payments for loss will be split between taxpayers and NFIP policyholders.
[15] See FEMA, Flood Insurance (2004) located at http://www.fema.gov/nfip/clientben.shtm
[16] An SBA loan is up to 50 percent of income for these damages.

To obtain the total assistance to individuals, the short-term housing Relocation assistance estimated in HAZUS is added to the cost of grants to residences. State funds in the flood assistance reaction function to residences are established using the matching formula in the Stafford Act.

Tax deductions are a potentially important source of relief to victims of a natural disaster. In the simulation, the proportion of individual losses entitled to tax breaks is calculated as the difference between flood losses and protection provided by insurance and federal relief grants. Specifically, in the assistance reaction function, the tax amount that flood victims are entitled to deduct is delineated by law. Victims of a natural disaster can deduct non-refunded losses after the natural disaster if losses are larger than 10 percent of the victim's annual income. For the deduction, we assign a default rate from tax-rate tables. Three income groups are considered: $0 to $30,000, $31,000 to $60,000, and greater than $60,000 with marginal tax rates of 20 percent, 26 percent and 30 percent, respectively. Total uncompensated damages are, therefore, flood loss minus the sum of compensation in the form of flood insurance, federal relief, and tax breaks. The SBA program generally involves a cost to the federal government that stems from expenses to operate the program, interest rate subsidies, and defaults. SBA budget reports for 2000 and 2002 indicate that the cost of the SBA program for disaster assistance is 9.8 percent of the loan amount.

Evaluation of payers of flood losses to residences will thus depend on the flood damage and the parameterizations in the assistance reaction function based on historical averages and Stafford Act. Table 3 details components of the federal reaction function (discussed in this section) that break down costs of flooded residences by payer. Figures 1 and 2 describe modules that transform estimated cost of flood losses from HAZUS and differentiate the flood losses by payer. Figure 1 shows who pays for flood losses for insured structures, and Figure 2 shows who pays for flood losses for uninsured structures.

TABLE 3: Components of Damage Assistance Relief for Residences

Equation A: Federal Relief for Residential Damages = Temporary Relocation + Individual Assistance Grants
Equation B: State Costs = State share × Equation A where the state share is calculated based on the upper bound of assistance relief to individuals delineated by Stafford Act, i.e., state share = 2,500/22,500 = 0.11.
Equation C: $\text{Latent Tax Relief} = \sum_{i}^{N_1+N_2} D_i \times \text{Tax Relief agent } i$ where $D_i = 1$, if non-refunded loss > 10 percent annual income, and $D_i = 0$, otherwise. Tax Relief agent i ={Uninsured Property Damage − Federal Relief - 10 percent of annual income} × Tax Rate where the analysis uses marginal tax rates of 20 percent, 26 percent and 30 percent for the income groups ($0-30K), ($31k-60k), and > $60K, respectively.
Equation D: Program Losses from the NFIP Subsidy = 0.6 × average NFIP loss per subsidized pre-FIRM structure x .0.29 of the number of all insured structures
Equation E: Uncompensated Damages = Uninsured Property Damage − Eq A − Eq C
Equation F: Value of SBA loans = Uninsured Flood Loss × 0.75 × 0.30
Equation G: Government Costs from SBA Loans: 0.098 × Equation F

Figure 1. Assistance Reaction Functions for Insured Residences

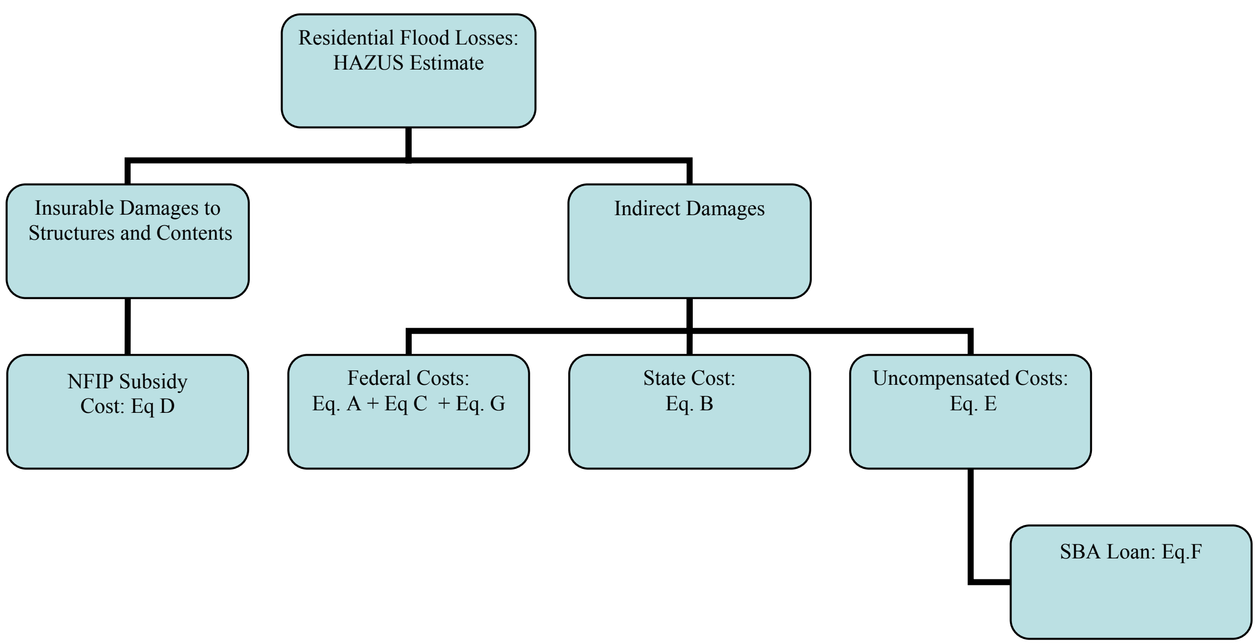
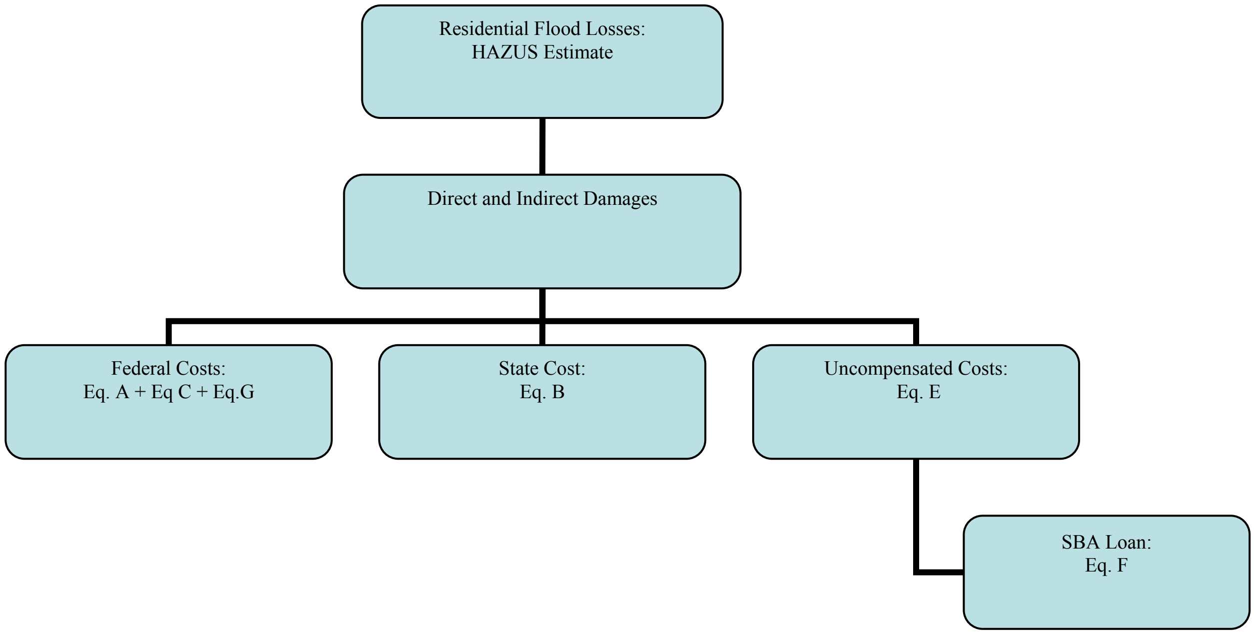


Figure 2. Assistance Reaction Functions for Uninsured Residences



Levels of compensation in the simulation under actual levels of insurance penetration are derived from a weighted average of estimates from the modules described in Figures 1 and 2.

From Figures 1-2, we can simulate the percentage of uncompensated damages to residences and the percentage of compensation to residences paid by taxpayers for insured and uninsured properties. The analysis also measures the impact of insurance coverage on this distribution of payers of flood losses. The distribution of payers can be evaluated by expected costs of flooding and medium and low probability floods (e.g., 10- and 100-year floods). We assume the average percentage of insurance penetration in SFHAs communities is 50 percent.[17] We also analyze penetration levels of 40 and 60 percent. Analysis of different insurance penetration levels shows the relation between federal relief and insurance.

[17] The RAND Corporation' study calculates a 50 percent insurance penetration in SFHAs.

4. NFIP'S IMPACT ON FLOOD LOSSES BY PAYER

This section examines the impacts that the NFIP and the elevation requirement have had on the costs of flooding and on their distribution among payers (SFHA residence, taxpayers, and the NFIP). We thus probe the NFIP's financial impact on who pays for flood disasters in SFHAs. An analysis by the National Weather Service (Pielke et al. 2002) yielded some insight by analyzing a 60-year series of the federal government's annual estimates of the costs of flooding, with the number of communities participating in the NFIP included as an explanatory variable. Federal flood disaster costs dropped significantly as NFIP participation rose. A shortcoming from econometric analyses, however, is that the assistance relief depends on the level of insurance penetration and vice versa. Perhaps, more importantly, time series econometric analysis cannot reliably separate savings from the NFIP mitigation standard from other factors that explain flood losses in SFHAs.

Flood losses and NFIP's impact per payer depends on the distribution of pre-FIRM and post-FIRM structures in SFHAs. Construction of post-FIRM structures has been regulated under national guidelines that require elevating new houses in SFHAs above the base flood elevation (BFE). Structures elevated above the BFE have a probability of less than one percent of being flooded in a 100-year flood. Pre-FIRM structures were not subject to floodplain management regulations unless they were substantially improved or repaired after substantial damage. The distribution of structures by BFE thus differs for pre-FIRM and post-FIRM structures. To estimate expected flood loss at the aggregate level across all SFHAs, we applied HAZUS to a set of communities with input data derived from the national distribution of structure elevations and from nationwide NFIP claims in SFHAs.

To evaluate flood costs by payer and the financial impact of the NFIP on SFHAs, we simulate losses under two scenarios. The first scenario captures flood losses under NFIP floodplain management guidelines (the elevation requirement) and current levels of flood insurance penetration. These guidelines require a new structure's lowest floor to be built at or above the base flood elevation (BFE), which is intended to reduce the probability of flood damages in structures to a frequency event of less than one percent per year. The second scenario simulates flood losses in the absence of floodplain management. The simulation decomposes the flood losses between payers and calculates the savings per payer from the NFIP mitigation standard. For this decomposition, we use our add-on modules (discussed in section 3) that break down HAZUS cost estimates by payer.

4.1. U.S. Multi-Hazard (HAZUS-MH) Flood Loss Simulation Model

The HAZUS simulation model yields direct economic losses to residences under different types of flooding. The level of aggregation in HAZUS is at the Census Block, i.e., flood losses are calculated at the mean characteristics at the Census Block. Economic losses in the flood model are built from actual geographical data extracted from Geographic Information System (GIS) maps. HAZUS contains a hydrologic model of the United States. This model builds on the U.S. Geologic Survey (USGS) EROS 30-meter digital elevation model, gauge records, USGS regressions for ungauged reaches, National Oceanic and Atmospheric Administration (NOAA) data, and the hydrologic derivatives. Census data at the block level are merged onto the geo-coded database. Guided by U.S. Department of Energy building characteristics survey data, structure characteristics are estimated. The HAZUS data file contains square feet of residential and commercial property by block. Starting from the NFIP loss database, the model examines losses in known flood events, infers total losses by cost category (essentially structure and contents), then uses these to drive an engine for estimating losses by flood size. HAZUS stores most data at the Census Block level, with the ability to aggregate blocks into counties or other reasonable units.

HAZUS simulates a water overflow for a given flood level, which results in the inundation of various Census Blocks in a community. From the resultant flood levels in each Census Block, HAZUS estimates economic losses through damage curves that are a function of the elevation of structures. In the simulation run for this analysis, expected damages for structures located below BFE are identified by computing whether a Census Block would flood under a "100-year" flood event (an event with 1 percent annual probability) and to what depth. Expected damages for structures at and above the BFE are calculated in terms of structures that are damaged only in the event of a flood level that surpasses a 100-year flood level. The level of aggregation in HAZUS is at the Census Block. Therefore, this criterion observes whether the average structure in the Census Block floods under a 100-year event. In addition to expected flood losses, we simulate losses for 5-, 10-, 25-, 50-, 100-, and 500- year floods, although we ultimately only report a subset of those simulations.

4.2. Impact Analysis of the Base Flood Elevation Standard: Expected Flood Losses Prevented per Year

To evaluate the financial impact of the NFIP, we combine secondary data available from PricewaterhouseCoopers (1999) with simulation data from HAZUS to analyze the NFIP's impact on the expected value of prevented losses at a national scale. Specifically, we simulated expected flood damages per year under the scenarios of NFIP and no-NFIP in SFHAs with secondary data providing national averages on the number of post-FIRM structures and the proportion of structures built below the BFE.

From secondary data,[18] 3.1 million structures in SFHAs are post-FIRM in the year 2004.[19] Therefore, if the expected damage of the average structure built at or above the BFE in the SFHA is EDy in year 2004, then the damages across all post-FIRM structures under the NFIP regulatory BFE criterion would be equal to:

$$\text{EDNFIP} = 3.1 \text{ million} \times \text{EDy}$$

To simulate flood losses in the absence of the NFIP, we assume the distribution of post-FIRM structures below the BFE is the same as for pre-FIRM structures. Pre-FIRM structures are not subject to the NFIP's building requirements. From PricewaterhouseCoopers (1999), an estimated 53 percent of pre-FIRM structures are located below the BFE in SFHAs. From this proportion of structures built without regulation, the simulated expected damage of a post-FIRM structure in the absence of the NFIP is:

$$\text{SNoNFIP} = (\text{EDn} \times 0.53) + (\text{EDy} \times 0.47)$$

where

[18] PricewaterhouseCoopers. A Study of the Economic Effects of Charging Actuarially Based Premium Rates for Pre-FIRM Structures. May 14, 1999

[19] This estimate is for the inventory of post-FIRM structures in the year 2004.

EDn = Expected damage for a structure built below the BFE in SFHAs

EDy = Expected damage for a structure built at or above the BFE in SFHAs.

As a result, expected flood losses of the 3.1 million post-FIRM structures built in SFHAs, if developed under the same elevation patterns as pre-FIRM structures (in the absence of the NFIP) would have been:

$$\text{EDNoNFIP} = 3.1 \text{ million} \times \text{SNoNFIP}$$

With the actual number of post-FIRM structures, the latent flood loss prevented by the NFIP norm is

$$\text{Latent NFIP prevention of damages} = \text{EDNoNFIP} - \text{EDNFIP}$$

The latent measure of NFIP prevention of damages captures the losses that could be avoided by elevating to BFE, but it does not account for noncompliance with the elevation requirement. To capture actual NFIP prevention of damages through compliance, we use secondary data that suggest 85% of post-FIRM structures are above the BFE (obtained from ISO Commercial Risk Services, 1996) to calculate actual prevention. As part of the national evaluation, after our simulations were completed, Mathis et al. (2006) estimated at a higher 89% compliance level with the BFE in post-FIRM structures. The 89%, however, included many buildings that met the elevation requirement but were not fully compliant with other floodplain management requirements and may still be subject to some damage. As a result, 85% remains a reasonable overall estimate of compliance for the purposes of the HAZUS model. With 85% compliance with BFE, total flood damages for compliant post-FIRM structures are

$$\text{AEDNFIP} = 3.1 \text{ million} \times (\text{EDy} \times 0.85);$$

and flood losses due to non-compliance with NFIP regulations (ANCNFIP) for post-FIRM structures are

$$\text{ANCNFIP} = 3.1 \text{ million} \times 0.15 \times \text{EDn}^*$$

where EDn* is the expected damage for non-complaint post-FIRM structures, i.e., post-FIRM structures built below the BFE in SFHA. We allow for the expected value of loses from non-compliance EDn* to be different for post-FIRM structures relative to losses of pre-FIRM structures located below the BFE. Therefore,

$$\text{NFIP prevention of damages} = \text{EDNoNFIP} - \text{AEDNFIP} - \text{ANCNFIP}$$

or, in other words, NFIP's impacts are expected losses under development patterns in SFHAs prior to the NFIP minus the expected losses under compliance as well as non-compliance.

In addition, the percentage increase of losses in the absence of the NFIP would have been

$$\%\text{AEDNFIP} = \text{EDNoNFIP} / (\text{AEDNFIP} - \text{ANCNFIP}) \times 100$$

where this is a relative (unit free) estimate of prevention. To estimate the expected value of prevented flood losses, this study uses HAZUS runs for a set of communities drawn from clusters of communities within SFHAs derived in the sub-study *An Evaluation of Compliance* *with the National Flood Insurance Program Part B: Are Minimum Building Requirements Being Met?*. The simulation is supplemented with structure data from the national distribution of elevations available from the PricewaterhouseCoopers (1999) and ISO Commercial Risk Services (1996) studies as well as insurance claims data. The use of national data from SFHAs allows estimation of the national impact of the NFIP in terms of prevention of flood losses to residences.

4.2.1. Calculation of Aggregate Expected Damages below BFE using National Averages

To estimate EDn, secondary data from PricewaterhouseCoopers (1999) establish that, of the pre-FIRM buildings in SFHAs that are below BFE, 55 percent are up to 2 feet below; 22.5 percent are located 3 to 5 feet below; and 22.5 percent are located 6 or more feet below. We incorporated this distribution of pre-FIRM elevations into HAZUS to estimate the aggregate expected flood damage.

The PricewaterhouseCoopers (1999) data, however, did not provide the distribution of elevations for post-FIRM structures located below the BFE. To approximate expected losses for non-compliant post-FIRM structures in SFHAs, the simulation uses average (historical) losses across all policies (with and without claims) of post-FIRM structures in SFHAs derived from claims data and reported in the NFIP Actuarial Rate Review 2004 (p. 24). Data on average losses for post-FIRM structures are added into HAZUS. That is, expected flood losses from non-compliance are calibrated to be consistent with total post-FIRM expected loss (from Actuarial Rate Review data). Expected losses from non-compliance are, in particular, derived assuming 15 percent non-compliance and using HAZUS estimates on losses below versus at or above BFE. Total flood losses for structures constructed below the BFE are the aggregate of losses from pre-FIRM structures constructed below the BFE and non-compliant post-FIRM structures.

4.3. Modules that Compute the Distribution of Payers under Each Scenario

The add-on modules in Section 4.2 break down the formulas in Section 5.2 that are not differentiated by payer. Among other results, we determine the extent to which the NFIP has (1) reduced the burden on victims and federal disaster relief and (2) increased the portion that SFHA residences pay of the risk premium associated with the choice to live in SFHAs. Thus, the analysis measures how the NFIP has fulfilled two of its main objectives.

To evaluate the financial impact of the NFIP by payer, we simulate three scenarios. First, we model flood losses and federal flood response costs for residences with NFIP insurance and NFIP-induced mitigation. Second, we simulate the losses with NFIP-induced mitigation but without insurance coverage. Last, we simulate losses in an unregulated system with neither mitigation nor insurance coverage (i.e., no NFIP). Figures 3-5 show the flood assistance reaction function that transforms HAZUS estimated cost of flood losses and differentiates the flood losses by payer under each scenario. Equations in the diagrams refer to the formulas in Table 3.

Figure 3. Assistance Reaction Functions for Insured Residences

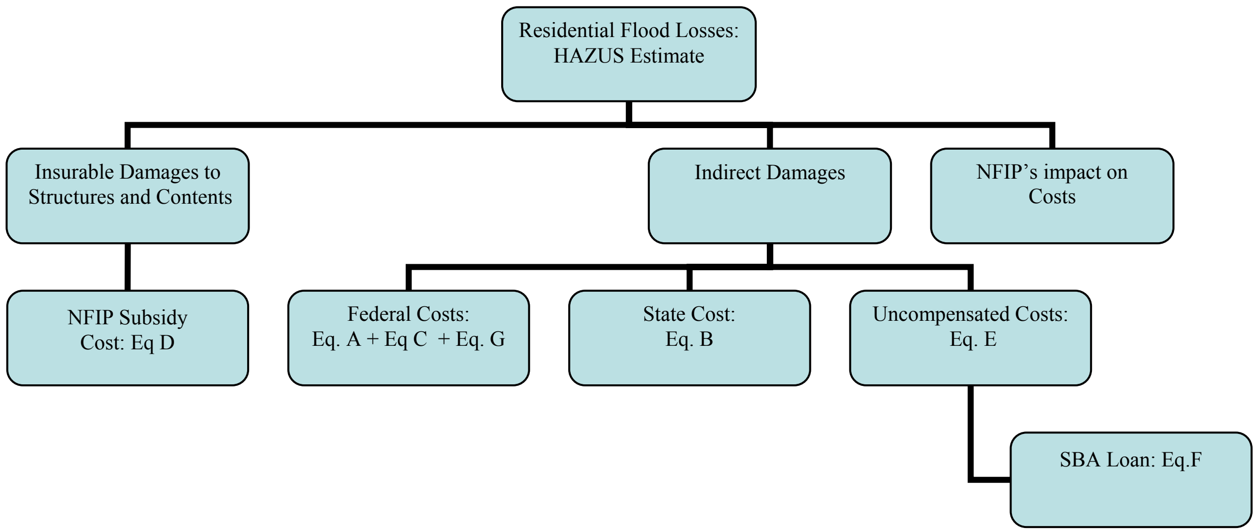
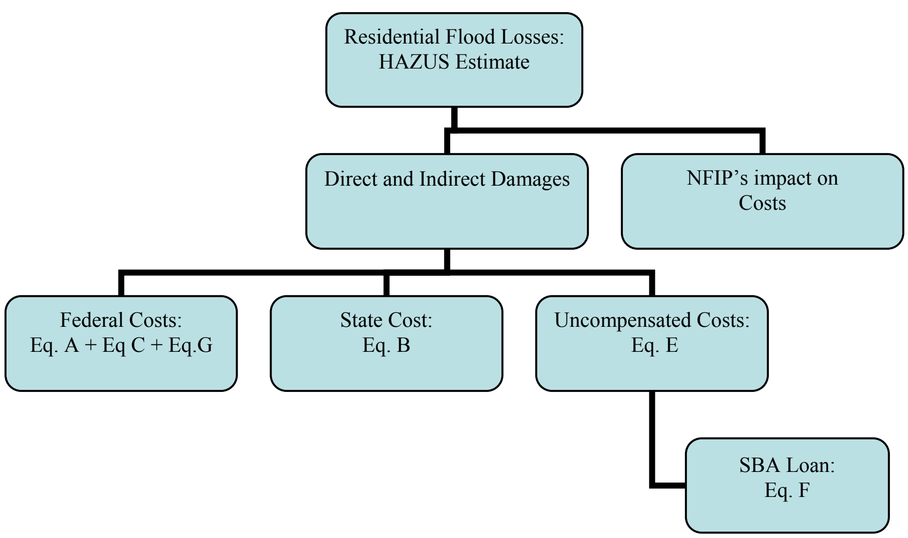
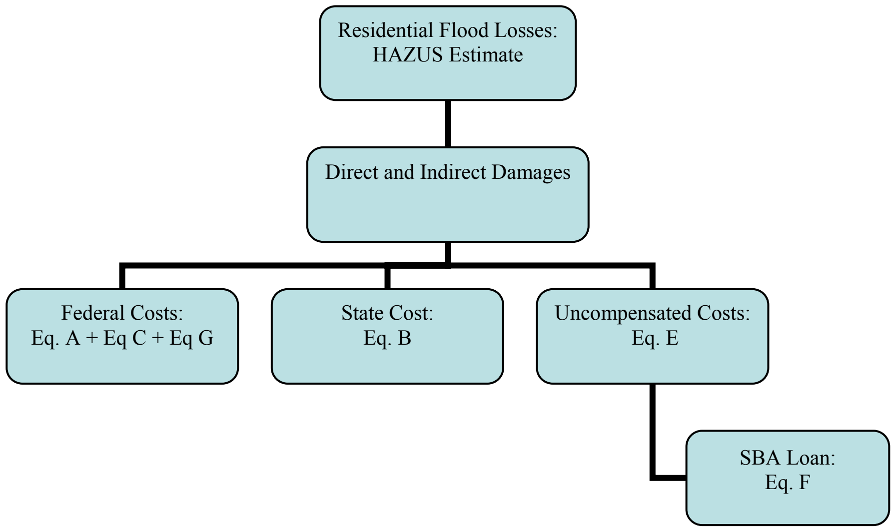


Figure 4. Assistance Reaction Functions for Uninsured Residences



Levels of compensation in the simulation under actual levels of insurance penetration are derived from a weighted average of estimates from the modules described in Figures 3 and 4. We also estimate the impact of the elevation requirement on who pays. The impact of the elevation requirement is estimated from simulated aggregate flood losses using the distribution of structures below BFE with and without the NFIP. For example, from section 5.2, modeling flood losses if the NFIP had not existed, 53 percent of post-FIRM structures would be below the BFE; with the NFIP, only 15 percent are below BFE. The simulated distribution of payers with and without the NFIP stems from comparing the outputs of the modules described in Figures 3-5.

Figure 5. Assistance Reaction Functions for Uninsured Residences and No-Mitigation



4.4. Evaluation of the Cost

From Figures 3-5, we simulate the percentage of uncompensated damages to residences and the percentage of compensation to residences paid by taxpayers for insured and uninsured properties. The analysis also measures the NFIP's impact on flood losses per payer. The evaluation of the cost of flooding uses the parameterizations in sections 5.2 to 5.3. The distribution of payers is evaluated by expected costs of flooding and for high, medium, and low probability floods (10-, 50-, and 100-year floods), as well as the 500-year flood.

The level of compensation under actual levels of insurance penetration is evaluated from a weighted average of estimates from modules that show the distribution of payers with and without insurance. We assume the average percentage of insurance penetration in SFHA communities as 50 percent.[20] We also analyze penetration levels of 40 and 60 percent. Analysis of different insurance penetration levels shows the relation between flood mitigation, federal relief, and insurance.

4.5. Data Extraction

To estimate expected flood loss at the aggregate level across all SFHAs, we applied HAZUS to a set of communities and added information on the national distribution of structural elevations and on NFIP claims in Section 5.2.

Our analysis of the dollar amounts of NFIP's impact on the costs of flooding and their distribution among payers uses flood losses extracted from 3,000 Census Blocks located at different flood risk levels (elevations), and selected from 20 communities that participate in the

[20] The NFIP Market Penetration substudy (Dixon et al , 2005) calculates an approximately 50 percent insurance penetration rate in SFHAs nationwide.

NFIP (see Table 4). The number of observations was limited because of the lengthy HAZUS running time required to upload a community's information to simulate economic losses. To choose the 20 communities, this study selected communities from a sample of clusters of NFIP communities included in Mathis et al. (2006). The sampling plan from that study allowed analysis of compliance within similar geographic areas, communities, flooding conditions, and building types. Eighteen "cluster areas" were identified in that study. Each cluster was composed of five randomly selected communities that met their criteria for inclusion in the study (i.e., community studied by detailed methods with 35 or more flood insurance policies in effect). To minimize bias in selecting communities to run in HAZUS from their community clusters, we picked randomly one community from each cluster. We added a flood-prone low-income community in Texas to gain better insight on low income communities. We also added Mecklenburg County, NC because this community was included in several aspects of the broader NFIP evaluation**.**

The NFIP's impact estimate in SFHAs is derived from evaluating total flood losses across Census Blocks with weights provided in Section 5.2. Furthermore, to model the institutional and economic framework of flood relief compensation, we apply the add-on-modules in Figures 3-5 to each Census Block. The modules break down the direct costs among payers, factoring in how the extent of damage affects the payer distribution. HAZUS allows the average loss per flood size to be evaluated. Using our add-on modules, HAZUS decomposes flood losses and NFIP's impact by payer in SFHAs.

TABLE 4. List of Communities

Community	Type of Watershed	Cluster from Community Compliance Sub-study*
Quincy, MA	Riverine	Northeast
City of Alexandria, VA	Riverine	Washington/Baltimore
St. Charles, MO	Riverine	Mississippi River
Covington, LA	Riverine	Louisiana
Saraland, AL	Riverine	Florida Panhandle
East Peoria, IL	Riverine	Great Lakes
Cass Co., ND	Riverine	Midwest
Frederick, CO	Riverine	Central Rockies
Mansfield, TX	Riverine	Texas – Central
Maricopa Co., AR	Riverine	Southwest
Fresno, CA	Riverine	California – South
Palo Alto, CA	Riverine	California – North
Sultan, WA	Riverine	Pacific Northwest
Mecklenburg County, NC	Riverine	Not clustered
Maverick, TX	Riverine	Not clustered
Galveston, TX	Coastal	Texas-Coastal
Bay Head, NJ	Coastal	Mid-Atlantic
Poquoson, VA	Coastal	Coastal North Carolina/Virginia
Jupiter, FL	Coastal	Florida –South
Dunedin, FL	Coastal	Florida – West Coast

*SOURCE: American Institutes for Research and Mathis and Nicholson, "*Evaluation of Compliance with the National Flood Insurance Program Part B: Are Building Requirements Being Met?* "

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5. RESULTS OF THE HAZUS MODELLING

5.1. Simulation of Total Losses and NFIP's Impact

HAZUS estimates the average expected annual flood loss across all pre-FIRM residences located below the BFE in SFHAs is $830. The average annual flood loss per post-FIRM residence built below the BFE in SFHAs is $462. By comparison, according to the NFIP's Actuarial Information System, the long-term average annual loss for insured properties at and above the BFE is $91 in riverine SFHAs and $297 in coastal SFHAs (V zones). All numerical calculations are in 2004 dollars.

HAZUS estimates that total residential flood costs in SFHAs are roughly $2.1 billion annually and that the NFIP annually saves an average of almost $1.1 billion in flood losses. This represents a one-third savings (1.1/(1.1+2.1)) on flood losses.

Table 5 shows the estimated damages per residence in SFHAs and the damages prevented by the NFIP. Annual flood loss per SFHA residence averages $290, while flood loss per SFHA residence located below the BFE averages $813. Under a 100-year flood, flood loss per SFHA residence averages $4,131 and flood loss for flooded structures averages $12,511.

TABLE 5: Flood Loss per SFHA Residence and the NFIP's Impact on That Loss

Loss Classification	Expected Annual Residential Flood Loss	Residential Flood Loss in a "100-year flood"
Flood Loss per Residence in SFHAs, with Mitigation Only	$290	$4,131
NFIP Impact on Flood Loss per Residence in SFHAs	$150	$2,334
Flood Loss per Residence Located Below the BFE in SFHAs	$813	$12,511

Note: For numbers underlying the estimates in a 100-year flood, see the "mitigation only" column in Table 9. Includes both pre- and post-FIRM residences in SFHAs.

The next section evaluates the impact of floodplain management on property values, with its indirect consequences on development in SFHAs. The evaluation of the capitalized flood loss in relation to property values uses the expected flood loss (in present value terms) over the lifetime of a typical mortgage.

5.2. Capitalized Value of Losses and NFIP Impact

Formulas available from financial economics can be used to calculate the effect of flood risk (or any other potentially recurring expense) on property values (Baker and Baker 2006). To capture the importance of flood losses relative to property values, we evaluate the expected flood loss (in present value terms) over the lifetime of a typical mortgage. This effect captures the wealth or capitalized effect of flood hazards and mitigation.

To calculate the capitalized effect of flood hazards on residences in SFHAs, specifically, we calculate the present value of expected flood losses under the standard 30-year mortgage. In the analysis, the expected flood loss for a period of 30 years is calculated using the average annual growth in the housing price index of 4.5 percent.[21] The present value term of the

[21] This average growth is calculated based on the observed growth of the housing price index in the last 30 years.

accumulated losses is obtained based on the average historic long run mortgage rate of 9 percent for a standard 30-year loan and discounting by the housing price index.[22] This present value term represents the expected loss in wealth due to floods from purchasing a residence in SFHAs. The financial calculation indicates that the flood hazard risk in SFHAs represents an average price discount (an accumulated expected flood loss in SFHAs) of $4,771 per structure. In the absence of the NFIP, the mean price discount would be $7,148 per structure. Therefore, the NFIP's impact on risk reduction expressed in terms of the mean price differential in the value of residences in SFHAs is $2,377.

Table 6 shows capitalized value of losses and NFIP's impact using the homeowner perspective under the average 30-year mortgage. The table also shows the present value under the social discount rate. This is a low risk or risk free discount rate and corresponds best to the nominal interest rate on long-term government bonds. In the table, the capitalized impact of the NFIP is $2,912 per structure. Thus, in terms of avoided losses in property values, the aggregate gain from the regulation of the existing 3.1 million post-FIRM structures in SFHAs is $9 billion. In addition to the NFIP impact on total cost, a breakdown of the NFIP's impact by payer underscores the effectiveness of the program in reducing cost to taxpayers as well as uncompensated losses.

TABLE 6: Capitalized Flood Loss and NFIP's Impact

Loss Classification	Capitalized Expected Residential Flood Loss (Historical Mortgage Rate)	Capitalized Expected Residential Flood Loss (Historical Prime Rate)
Capitalized Total Flood Cost per Residence in SFHAs	$4,771	$5,725
Capitalized NFIP Impact on Flood Cost per Residence in SFHAs	$2,377	$2,912
Capitalized Total Flood Cost per Residence Located Below the BFE in SFHAs	$14,425	$16,107

5.3. Simulation of Flood Losses and NFIP's Impact by Payer

The NFIP has clearly induced savings on flood costs. Moreover, flood insurance has shifted the loss from taxpayers to those who pay the insurance premium. Indeed, the NFIP objectives were twofold: (1) constraining the cost of damage caused by flooding, and (2) providing economically feasible relief to victims through insurance. This section applies the institutional and economic framework of flood relief compensation described in Section 5.3 to different simulated flood levels yielding: costs to flood victims, federal disaster relief costs, costs to taxpayers, and costs to the NFIP. In addition to the breakdown of the cost estimates by payer, this section evaluates the impact of NFIP floodplain management guidelines (the elevation requirement) on flood losses by payer in SFHAs.

The simulation estimates how extensively the NFIP has aided victims and reduced disaster relief costs, and how well the NFIP has addressed the aim that those who choose to live in flood hazard areas pay the risk premium associated with their choices. Decomposition of payers and evaluation of the NFIP's impact uses annual expected losses. In the financial analysis of flood losses, we also decompose the flood damages per structure for different flood sizes and

[22] Use of historic rate for 15-year averages with a mean housing price index of 3 percent and mortgage rate of 7.5 percent yields capitalization estimates that vary less than 1 percent relative to the use of 30-year averages.

evaluate the tax that society pays per structure in SFHAs. The latter estimate captures the flood costs that residences in SFHAs impose on society, a very important economic indicator.

In particular, we incorporate the parameterization of the federal response function in Figures 3 and 5 (under the parameterization discussed in section 4.3) to HAZUS flood damage curves. Table 7 shows average annual flood losses for residences in SFHAs and breaks the losses down by payer. It also details the loss reduction resulting from the NFIP.

Tables 7-12 follow a common format. The columns in the table show the losses and savings with mitigation only and with 40%, 50%, and 60% NFIP insurance penetration in SFHAs. The rows in each table are divided into three panels. The top panel describes the loss due to floods, breaking it down into loss paid by the federal government, loss paid by state governments, uncompensated loss to individuals, and loss paid by the NFIP from the pooled premiums collected from NFIP policy holders. The middle panel details the federal loss, showing estimated loss on SBA loans, FEMA individual assistance and temporary relocation grants net of state matching funds, and the revenue loss from partial income tax write-offs of uncompensated losses. A last row in this panel shows the NFIP long-term loss that results from discounting rates for pre-FIRM structures built below BFE. Numbers from that row are excluded from totals shown in the tables because it is unclear who ultimately will pay for the loss that resulted from the Congressionally mandated discounts. The bottom panel shows the loss reduction that resulted from the NFIP. It distinguishes federal savings due to NFIP insurance sales and NFIP-induced mitigation, state savings, and reductions in private loss. Private loss includes both uncompensated loss and loss paid by NFIP policyholders who have pooled their risks. As NFIP penetration rises, federal and state loss decline, offset by a rise in loss compensated by NFIP claims payments.

Annually, for example, the top panel of Table 7 shows that expected flood losses in SFHAs will be roughly $2.1 billion. At 50 percent insurance penetration (the current average nationwide), federal and state government will bear about $350 million ($333 million plus $16 million), NFIP claims payments will cover more than $950 million, and $770 million in loss will not be compensated. According to the middle panel of Table 7, more than half of the federal loss will result from income tax write-offs of uncompensated flood loss. The loss from discounting rates to pre-FIRM structures below BFE is one and one third times the loss from federal financial assistance and tax write-offs combined. Overall, NFIP penetration and mitigation annually will reduce loss by an estimated $1.1 billion, with the savings split almost equally between the government and NFIP policyholders (from the bottom panel of Table 7).

Results from all the tables are discussed below. Table 8 is a companion to Table 7. While Table 7 shows estimates of total expected annual loss nationwide, Table 8 shows expected loss per residence. The loss estimates in Table 8 are smaller than the estimates in later tables, which show loss per residence in floods of different sizes, because those tables include the loss if a flood occurs for properties that would be unlikely to face a flood in a one-year time horizon.

TABLE 7: Expected Annual Flood Loss in SFHAs by Payer (dollars in millions)

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$574	$381	$333	$283
Loss Paid by State Government	$31	$19	$16	$13
Uncompensated Loss to Individuals	$1,502	$917	$771	$625
NFIP Claims Payments	$0	$760	$953	$1,145
Total Loss from Floods, All Payers	***$2,107***	***$2,077***	***$2,073***	***$2,076***
b. Federal Loss				
Amount of SBA Loans Lost	$41	$25	$21	$16
FEMA Individual Assistance	$124	$75	$63	$51
Temporary Relocation	$85	$85	$85	$85
Tax Write-Offs	$357	$215	$179	$144
Less: Loss Paid by State Government.	-$31	-$19	-$16	-$13
Total Loss Paid by Federal Government Due to Floods	***$574***	***$381***	***$333***	***$283***
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$365	$457	$548
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$193	$241	$291
Decrease in Federal Loss Due to NFIP Mitigation	$286	$286	$286	$286
Total Decrease in Federal Loss Due to NFIP	*$286*	*$479*	*$527*	*$577*
Decrease in State Loss	$17	$29	$32	$35
Decrease in Private Loss[2]	$770	$586	$529	$483
Total Loss Reduction from NFIP	**$1,073**	**$1,094**	**$1,088**	**$1,095**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

To provide further insight, Tables 9-12 show expected annual losses and estimated actual damage (under selected flood sizes) per residence and the proportions each payer bears of the damages under different flood sizes. The analysis of the expected and actual financial impacts of floods measures the NFIP's impact on uncompensated flood losses per residence in SFHAs and the impact of insurance on costs to government.

TABLE 8: Expected Flood Loss by Payer per Residence in SFHAs

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$81	$54	$46	$40
Loss Paid by State Government	$4	$3	$2	$2
Uncompensated Loss to Individuals	$213	$129	$109	$88
NFIP Claims Payments	$0	$107	$134	$161
Total Loss from Floods, All Payers	***$298***	***$283***	***$293***	***$291***
b. Federal Loss				
Amount of SBA Loans Lost	$6	$3	$3	$2
FEMA Individual Assistance	$17	$11	$9	$7
Temporary Relocation	$12	$12	$12	$12
Tax Write-Offs	$50	$30	$25	$20
Less: Loss Paid by State Government.	-$4	-$3	-$2	-$2
Total Loss Paid by Federal Government Due to Floods	**$81**	**$54**	**$46**	**$40**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$53	$66	$79
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$27	$34	$41
Decrease in Federal Loss Due to NFIP Mitigation	$40	$40	$40	$40
Total Decrease in Federal Loss Due to NFIP	*$40*	*$67*	*$74*	*$81*
Decrease in State Loss	$2	$3	$4	$4
Decrease in Private Loss[2]	$108	$84	$77	$71
Total Loss Reduction from NFIP	**$150**	**$154**	**$155**	**$156**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

Table 9 is the most important of Tables 9-12 because it shows losses for the 100-year flood, a flood at the mitigation protection level required by NFIP floodplain management regulations. Table 9 shows expected losses and savings at that protection level. Totals from this table appear in Table 5. Tables 10-12 show similar breakdowns of expected losses for 10-year, 50-year, and 500-year floods. Both compensated and uncompensated losses rise with flood size.

TABLE 9: Flood Loss by Payer per Residence in SFHAs for a 100-Year Flood

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$1,414	$938	$819	$700
Loss Paid by State Government	$90	$55	$46	$36
Uncompensated Loss to Individuals	$2,718	$1,673	$1,412	$1,151
NFIP Claims Payments	$0	$1,519	$1,899	$2,279
Total Loss from Floods, All Payers	***$4,232***	***$4,185***	***$4,176***	***$4,166***
b. Federal Loss				
Amount of SBA Loans Lost	$90	$54	$45	$36
FEMA Individual Assistance	$359	$219	$184	$149
Temporary Relocation	$211	$211	$211	$211
Tax Write-Offs	$844	$508	$424	$340
Less: Loss Paid by State Government.	-$90	-$55	-$46	-$36
Total Loss Paid by Federal Government Due to Floods	**$1,414**	**$938**	**$819**	**$700**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$778	$972	$1,167
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$476	$599	$714
Decrease in Federal Loss Due to NFIP Mitigation	$817	$817	$817	$817
Total Decrease in Federal Loss Due to NFIP	$817	$1,293	$1,416	$1,531
Decrease in State Loss	$62	$97	$106	$116
Decrease in Private Loss[2]	$1,520	$1,046	$927	$808
Total Loss Reduction from NFIP	**$2,399**	**$2,436**	**$2,449**	**$2,455**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

TABLE 10: Flood Loss by Payer per Residence in SFHAs for a 10-Year Flood

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$254	$163	$140	$117
Loss Paid by State Government	$13	$8	$7	$5
Uncompensated Loss to Individuals	$850	$502	$422	$341
NFIP Claims Payments	$0	$383	$486	$589
Total Loss from Floods, All Payers	***$1,117***	***$1,026***	***$1,057***	***$1,052***
b. Federal Loss				
Amount of SBA Loans Lost	$20	$12	$10	$8
FEMA Individual Assistance	$53	$32	$27	$21
Temporary Relocation	$26	$26	$26	$26
Tax Write-Offs	$168	$101	$84	$67
Less: Loss Paid by State Government.	-$13	-$8	-$7	-$5
Total Loss Paid by Federal Government Due to Floods	**$254**	**$163**	**$140**	**$117**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$214	$267	$321
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$91	$114	$136
Decrease in Federal Loss Due to NFIP Mitigation	$151	$151	$151	$151
Total Decrease in Federal Loss Due to NFIP	$151	$242	$265	$287
Decrease in State Loss	$9	$14	$15	$17
Decrease in Private Loss[2]	$443	$408	$385	$363
Total Loss Reduction from NFIP	**$603**	**$664**	**$665**	**$667**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

TABLE 11: Flood Loss by Payer per Residence in SFHAs for a 50-Year Flood

Loss Component	Expected Loss (Mitigation Only)	Expected Loss (Insurance Penetration = 40%)	Expected Loss (Insurance Penetration = 50%)	Expected Loss (Insurance Penetration = 60%)
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$782	$507	$439	$370
Loss Paid by State Government	$59	$36	$30	$24
Uncompensated Loss to Individuals	$1,631	$1,000	$842	$684
NFIP Claims Payments	$0	$908	$1,135	$1,362
Total Loss from Floods, All Payers	***$2,472***	***$2,451***	***$2,446***	***$2,440***
b. Federal Loss				
Amount of SBA Loans Lost	$51	$31	$26	$20
FEMA Individual Assistance	$236	$143	$120	$97
Temporary Relocation	$92	$92	$92	$92
Tax Write-Offs	$462	$277	$231	$185
Less: Loss Paid by State Government.	-$59	-$36	-$30	-$24
Total Loss Paid by Federal Government Due to Floods	**$782**	**$507**	**$439**	**$370**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$476	$595	$714
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$275	$343	$412
Decrease in Federal Loss Due to NFIP Mitigation	$456	$456	$456	$456
Total Decrease in Federal Loss Due to NFIP	$456	$731	$799	$868
Decrease in State Loss	$39	$62	$68	$74
Decrease in Private Loss[2]	$919	$642	$573	$504
Total Loss Reduction from NFIP	**$1,414**	**$1,435**	**$1,440**	**$1,436**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

TABLE 12: Flood Loss by Payer per Residence in SFHAs for a 500-Year Flood

Loss Component	Expected Loss (Mitigation Only)	Expected Loss (Insurance Penetration = 40%)	Expected Loss (Insurance Penetration = 50%)	Expected Loss (Insurance Penetration = 60%)
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$3,762	$2,565	$2,265	$1,966
Loss Paid by State Government	$152	$94	$80	$65
Uncompensated Loss to Individuals	$6,665	$4,117	$3,480	$2,843
NFIP Claims Payments	$0	$3,715	$4,644	$5,573
Total Loss from Floods, All Payers	**$10,579**	**$10,491**	**$10,469**	**$10,447**
b. Federal Loss				
Amount of SBA Loans Lost	$225	$137	$114	$92
FEMA Individual Assistance	$607	$376	$319	$261
Temporary Relocation	$723	$723	$723	$723
Tax Write-Offs	$2,359	$1,423	$1,189	$955
Less: Loss Paid by State Government.	-$152	-$94	-$80	-$65
Total Loss Paid by Federal Government Due to Floods	**$3,762**	**$2,565**	**$2,265**	**$1,966**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Structures[1]	$0	$1,468	$1,834	$2,201
c. Loss Reduction Due to NFIP				
Decrease in Federal Loss Due to NFIP Insurance Penetration	$0	$1,197	$1,497	$1,796
Decrease in Federal Loss Due to NFIP Mitigation	$1,413	$1,413	$1,413	$1,413
Total Decrease in Federal Loss Due to NFIP	$1,413	$2,610	$2,910	$3,209
Decrease in State Loss	$111	$169	$183	$198
Decrease in Private Loss[2]	$2,578	$1,411	$1,119	$828
Total Loss Reduction from NFIP	**$4,102**	**$4,190**	**$4,212**	**$4,235**

Notes:
Totals do not match exactly between columns due to rounding.
Includes both pre- and post-FIRM residences in SFHAs
[1] The loss from discounted rates to pre-FIRM structures is not included in the Total Loss in sections b or c.
[2] Private loss includes loss compensated by flood insurance (NFIP Claims Payments plus Uncompensated Loss to Individuals). As NFIP coverage rises, losses shift from the public sector to private property owners who have pooled their risks.

5.4. Financial Impact of the NFIP

The simulation analysis of flood costs by payer establishes that flood mitigation and insurance reduce annual total flood losses in SFHAs. With the average insurance penetration in SFHAs in 2004 of 50 percent,[23] as reported in the bottom two panels of Table 7, the simulation shows that the NFIP reduces annual expected costs to the federal government for buildings and their contents by $527 million (reducing costs from $860 million down to $333 million, with $286 million of the savings due to improved flood outcomes and $241 million due to insurance coverage of losses). That amounts to a 71-percent cost reduction. The expected cost to the NFIP of discounts to pre-FIRM structures is $457 million (from the middle panel), almost half of NFIP outlays. The expected cost of the discounts is not incorporated in the insurance premium and constitutes financial risk to the NFIP. The expected reduction of uncompensated losses to individuals through improved floodplain management (from the first column of data) required by the NFIP is even larger at $770 million, a one third reduction in the cost. Insurance (at a market penetration level of 50 percent) reduces expected annual uncompensated losses by an additional $731 million ($1,502 million - $771 million from the first and third columns of the top panel) with residual uncompensated losses at $771 million.

Table 7 breaks down who pays for flood losses under different levels of insurance penetration. With 40-percent penetration, the NFIP reduces annual expected loss to the federal government by $479 million (with $193 million due to insurance coverage of losses), which amounts to a 56 percent loss reduction ($479 million/($381 million + $479 million)). The NFIP loss on subsidies to pre-FIRM structures is $132 million. The NFIP reduces expected uncompensated loss to individuals by $1.355 billion ($1,502 million - $917 million + $770 million), a 60 percent loss reduction, with insurance contributing $585 million ($1,502 million - $917 million). With insurance penetration at 60 percent, the NFIP reduces uncompensated losses by an estimated $1.65 billion, a 73 percent reduction in flood loss.

Continuing the financial analysis of flood loss, we estimate the flood loss per residence for different flood sizes and evaluate the government loss per residence in SFHAs. The latter estimate captures the flood costs that residences in SFHAs impose on society. For example, at a 50-percent insurance penetration level, Table 8 shows that the average SFHA residence generates an annual cost of $48 to taxpayers ($46 in federal loss + $2 in state loss). The NFIP has reduced the flood-related tax burden per residence by $78 ($74 federal + $4 state) with mitigation accounting for a $42 reduction ($40 federal + $2 state) and insurance coverage accounting for $36. With insurance penetration at 40 percent, instead of 50 percent, government loss would rise from $48 to $57 per structure.

The expected annual flood-related loss in SFHAs with NFIP mitigation but no insured residences (the first data column in Table 8) would average $298 per residence. Without the NFIP mitigation program, the annual flood related loss would be $448 ($298 + $150). With 50-percent insurance penetration, the NFIP reduces average annual flood loss by $289 per residence and the expected uncompensated loss per residence is $109.

[23] In the market penetration study, the RAND Corporation sub-study (Dixon et al., 2005) estimates that the average insurance penetration in SFHAs is 50 percent

The simulation also illustrates limitations of the NFIP after the occurrence of a low probability, high cost flood disaster. For example, under a 500-year flood (Table 12), that is, a flood with a probability of only 0.2 percent every year, the NFIP reduces losses by 46 percent ($8,856/($8,856 + $10,469)) at 50-percent penetration. After a 10-year flood, the loss reduction due to the NFIP is 51 percent ($2,545/ ($2,545 + $2,446)). The effect of the mitigation regulations on flood loss rises with flood size. In percentage terms, mitigation reduces loss in floods up to the 100-year flood by roughly 36 percent but reduces the loss in a 500-year flood by only 28 percent.

5.4.1. Impact of the NFIP on Costs of Floods of Different Sizes

An aim of the NFIP is to reduce governmental costs after a major disaster. This section examines the NFIP's impact on loss per residence after a 100-year flood for the average SFHA residence with 50-percent insurance penetration. Results also show the costs of relief assistance after a 100-year flood. Tables 10-12 provide comparable information for 10-year, 50-year, and 500-year floods, but those results largely are not discussed here.

From Table 9, after a 100-year flood, the NFIP reduces average uncompensated loss by $1,520 through flood mitigation and by $1,316 ($2,718 - $1,412) through flood insurance penetration. It reduces total government loss in a 100-year flood by an estimated $1,522 per residence in the affected SFHA ($1,416 + $106). This includes federal government savings of $817 through mitigation and $599 through penetration. Increasing insurance penetration from 50 to 60 percent would reduce government costs by another $125 per residence.

With 50 percent penetration, uncompensated loss per residence averages $1,412, federal loss averages $819, and state loss averages $46. The burden on taxpayers is $865 per residence ($819 + $46). Without the NFIP, the burden on taxpayers would average $2,383 per residence in the SFHA ($1,414 + $90 + $817 + $62). Thus, the NFIP's estimated cost savings to taxpayers is $1,518 per residence, a 64-percent cost reduction (1,518/$2,383).

Looking across Tables 9-12, federal spending for temporary relocation (temporary housing) increases with flood size faster than other components of federal relief. For example, with 50-percent insurance penetration in the SFHA, the ratio of temporary relocation costs to individual assistance is 0.96 after a 10-year flood and 2.27 after a 500-year flood.

Overall, in Tables 6-12, the impact of the NFIP on flood loss prevention and the NFIP's impact by payer underscore the effectiveness of regulation in SFHAs. The results also underscore the cost of development in SFHAs to taxpayers and to residents and property owners in these high risk areas. The annual expected cost to taxpayers from residences in SFHAs is $333 million, and expected annual uncompensated losses are $771 million. The NFIP has reduced federal spending on floods by 61 percent. The tables highlight expected federal and state government losses and uncompensated loss per residence after floods of varying size.

5.5. Who Pays for Losses to Residences Located Below the BFE in SFHAs

To understand better the costs and consequences of flooding, this section decomposes who pays for losses of high-risk pre-FIRM residences located below the BFE in SFHAs. Results that capture the flood costs from residences located below the BFE in SFHAs underscore the implicit tax to society generated by these residences. As in Section 6.4, the analysis uses the breakdown by payer computed with the methodologies in Sections 4 and 5. Estimates in Tables

6-12 included all residences in SFHAs. This section instead estimates who pays per SFHA residence that floods in a 100-year flood. Since residences elevated to the 100-year base flood elevation should not flood in a 100-year flood, we label this group of flooded properties as residences below the BFE. In some cases, they may be grandfathered properties that were built to the BFE before remapping found the expected flood depth had risen or BFE-compliant properties whose expected flood depths would rise if they were remapped.

Tables 13-14 follow essentially the same format as Tables 7-12 but the third section of the table is omitted because pre-FIRM residences have not benefited from most NFIP mitigation efforts. Table 13 indicates that the average annual cost of flooding for a pre-FIRM SFHA residence below the BFE without insurance is $829, well above the $298 average for all SFHA residences (from Table 8). Moreover, assuming 50 percent insurance coverage, these high risk residences in SFHAs impose a burden of $125 per residence to taxpayers (compared to the $46 burden for all residences from Table 8). If the insurance coverage were 40 percent or 60 percent, the burden to taxpayers would be $143 and $106, respectively. Furthermore, for the average residence located below BFE, the expected expense for the NFIP in outlays for claim payments assuming 50 percent market penetration is $381 with the subsidy paying $195 of these expenses.[24] Assuming 60 percent insurance penetration, the outlays for the NFIP in claim

TABLE 13: Expected Flood Loss by Payer per Pre-FIRM Residence Located Below the BFE in SFHAs

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$219	$143	$125	$106
Loss Paid by State Government	$12	$7	$6	$5
Uncompensated Loss to Individuals	$598	$368	$310	$251
NFIP Claims Payments	$0	$304	$381	$458
Total Loss from Floods, All Payers	***$829***	***$822***	***$822***	***$820***
b. Federal Loss				
Amount of SBA Loans Lost	$16	$10	$8	$6
FEMA Individual Assistance	$47	$29	$24	$19
Temporary Relocation	$28	$28	$28	$28
Tax Write-Offs	$140	$84	$70	$56
Less: Loss Paid by State Government.	-$12	-$7	-$6	-$5
Total Loss Paid by Federal Government Due to Floods	**$219**	**$143**	**$125**	**$106**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Residences[1]	$0	$155	$195	$234

Notes:
Totals do not match exactly between columns due to rounding.
[1] The loss from discounted rates to pre-FIRM residences is not included in the Total Loss in section b.

[24] This estimate was calculated by multiplying the NFIP outlays by the average subsidy (60 percent) and the percentage of structures below the BFE that received subsidies (53 percent).

payments is $458 per residence with the subsidy paying $234, or about half, of these expenses. Assuming 50 percent insurance penetration, uncompensated losses per residence located below the BFE are $310. If the insurance penetration increases from 50 to 60 percent, uncompensated loss per residence decreases $59, a 19 percent decrease.

Table 14 shows the NFIP's impact after a 100-year flood event for the average pre-FIRM residence that floods (i.e., located below BFE) assuming 50 percent flood insurance market penetration in SFHAs. Estimates from this table can be compared with Table 9. For the average residence below BFE flooded during a 100-year flood event, the uncompensated loss is $4,276, and the loss to the federal government is $2,480. Thus, the burden of residences affected by a 100-year flood which is passed to the taxpayers is $2,480 per residence that flooded. By comparison, across all residences in the SFHA, uncompensated loss from a 100-year flood averages $1,412 and loss to the Federal government averages one fourth of the loss for a residence below the BFE, $819.

TABLE 14: Flood Loss by Payer per Pre-FIRM Residence Located Below the BFE in SFHAs Affected by a 100-Year Flood

Loss Component	**Expected Loss (Mitigation Only)**	**Expected Loss (Insurance Penetration = 40%)**	**Expected Loss (Insurance Penetration = 50%)**	**Expected Loss (Insurance Penetration = 60%)**
a. Loss Due to Floods, All Payers				
Total Loss Paid by Federal Government	$4,277	$2,839	$2,480	$2,121
Loss Paid by State Government	$274	$167	$141	$114
Uncompensated Loss to Individuals	$8,233	$5,067	$4,276	$3,485
NFIP Claims Payments	$0	$4,602	$5,752	$6,902
Total Loss from Floods, All Payers	***$12,874***	***$12,675***	***$12,649***	***$12,622***
b. Federal Loss				
Amount of SBA Loans Lost	$271	$164	$137	$110
FEMA Individual Assistance	$1,094	$668	$562	$456
Temporary Relocation	$644	$644	$644	$644
Tax Write-Offs	$2,540	$1,530	$1,277	$1,024
Less: Loss Paid by State Government.	-$274	-$167	-$141	-$114
Total Loss Paid by Federal Government Due to Floods	**$4,277**	**$2,839**	**$2,480**	**$2,121**
NFIP Long-term Loss from Discounted Rates to Pre-FIRM Residences[1]	$0	$2,353	$2,940	$3,528

Notes:
Totals do not match exactly between columns due to rounding.
[1] The loss from discounted rates to pre-FIRM residences is not included in the Total Loss in section b.

5.5.1. The Relationship between Expected Flood Losses below BFE and the Price of Residences

Assuming that estimated flood risk is capitalized in housing prices, we also estimated the effect of flood risk on property values for residences located below the BFE. Financial analysis of the expected flood loss to residences located below BFE indicates that the risk discount expressed in terms of property values (present value of expected loss over the lifetime of a typical mortgage) is $14,425. The simulation also permits examination of the expected flood loss effects on property values under the NFIP's requirement that residences must purchase flood insurance to quality for federally-sponsored mortgage loans in SFHAs. The simulated reduction in property values from expected flood losses for insured residences located below the BFE is $16,010 (measured at the historic mark up of 1.16 for subsidized rates for pre-FIRM residences).[25] Without the subsidy of 60 percent of the insurance premium for pre-FIRM residences located below the BFE, the impact of flood losses for residences located below BFE on the price of housing would average a total of $40,035 in costs per residence. Thus, the flood insurance subsidy introduced an appreciation of $24,020 in property values to the subsidized pre-FIRM residences that comprise most of the residences located below the BFE.

The market distortion from the subsidy is more than 15 percent of the mean pre-FIRM property value, $158,000, in 2004 and, thus, preserves market value of some high risk properties.

Finally, from the simulation, the capitalized values of expected losses of pre-FIRM and post-FIRM residences are, respectively, $7,182 and $1,651. Table 15 shows capitalization estimates using mortgage and prime rates. Therefore, while the NFIP partly contributes to development by protecting against catastrophic risk, the expected loss over the lifetime of a typical mortgage for a typical post-FIRM residence is only $1,651, about one percent of the mean post-FIRM house value ($197,000). This indicates that while considerable development has occurred in SFHAs, the economic impact of flood hazard risk for each of these new residences is small.[26] These estimates ignore the cost of mitigation, which offsets somewhat the savings achieved by reducing flood damages. The study does not measure any added value to individuals of the reduction in risk of catastrophic financial losses that results from spreading risk by purchasing actuarially sound flood insurance.

TABLE 15: Capitalized Flood Loss by Type of Residences

Loss Classification	Capitalized Expected Residential Flood Loss (Historical Mortgage Rate)	Capitalized Expected Residential Flood Loss (Historical Prime Rate)
Capitalized Total Flood Cost per Pre-FIRM Residence in SFHAs	$7,182	$8,618
Capitalized NFIP Impact on Flood Cost per Post-FIRM Residence in SFHAs	$1,651	$1,980

[25]See Actuarial Rate Review (Hayes and Sabade, 2004)

[26] Further, as indicated in the sub-study "The National Flood Insurance Program: Developmental and Environmental Impacts," there is evidence that development would occur in many areas with high flood risks regardless of the existence of the program.

5.6. Summary of the HAZUS Analysis

The HAZUS simulation examined the impact of flood mitigation requirements on savings on residential flood losses and the loss distribution among payers. The analysis probed the NFIP's financial impact, a central question about program effectiveness. Using simulation software, unlike using econometric analysis, permitted an analysis of the impact of flood mitigation on who pays for flood disasters and provided the flexibility to control for the size of the flood and its impact on flood assistance relief.

The empirical results establish that flood mitigation and insurance reduce total annual flood losses in SFHAs. For example, with the 50-percent average flood insurance market penetration rate in SFHAs, the simulation analysis estimates that the NFIP reduces annual expected costs to the federal government by $527 million with $241 million due to insurance coverage of losses and $286 due to mitigation. The expected cost to the NFIP of discounts or subsidies to pre-FIRM residences is $457 million, about half of total NFIP outlays. The NFIP reduces uncompensated losses to individuals by an estimated $1.5 billion, with insurance payments contributing $731 million and mitigation contributing $770 million.

The HAZUS analyses estimate flood loses and flood-related tax write-offs per residence in SFHAs. We analyze three insurance penetration levels and a mitigation-only case and estimate the damages in 10, 50, 100, and 500 year floods as well as for the blended risk of floods of all probabilities (frequencies) in a year. We also analyze the effect of the NFIP on property value. Moreover, we calculate the effects of flood risk, mitigation, and flood insurance coverage costs on property values for pre-FIRM and post-FIRM residences in SFHAs. The financial analysis estimates the flood-related cost that development in SFHAs imposes on taxpayers (due to flood disaster assistance, subsidized loans, and income tax write-offs of losses) as well as on owners and occupants of residences located in flood risk areas (either directly or through NFIP claims payments). The NFIP affects these costs by shifting some covered losses from taxpayers to policyholders and by requiring mitigation measures that may reduce flooding or reduce property damage when floods occur. The financial impact of the NFIP on mitigation and on who pays are excellent measures of the costs and consequences of floodplain regulation.

The common belief that the NFIP has stimulated development that increased flood losses is not supported by our findings that with mitigation, flood hazards associated with most new development have a relatively small effect on property values. In contrast, the NFIP subsidy to pre-FIRM residences below BFE has artificially increased market value of these high-risk residences and buildings. Thus, the subsidy has contributed to maintaining market demand for pre-FIRM residences located below BFE. If the buildings were replaced or substantially renovated, the subsidies would be lost. Thus, rate discounts discourage investment that would have raised elevations above BFE. From a public policy perspective, however, redevelopment seems desirable; it would force elevation of the buildings to BFE, meaning they were less subject to flood damage.

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6. ANALYSIS OF FLOOD LOSSES BY INCOME GROUP

With $2 billion in property losses per year, flood events cause more losses, on average, than any other natural disaster in the United States. Flood losses by income and ethnic group partly depend on whether floodplain management and insurance programs reach disadvantaged populations and minorities, a key measure of program equity. Disadvantaged populations often lack flood insurance and the loss for the poor is in many cases irreparable. Indeed, if the population that lives in poverty is most significantly affected by flood hazards, more effective mechanisms for coordinating local, state and federal response are needed. The poverty line depends on the size and composition of the family with regard to the number of children, adults and persons age 65 or over. For example, the poverty line (or threshold) in 2002 was $9,183 for a one-person family, $18,244 for a four-person family with two children (under age 18), and $18,307 for a four-person family with three children. In this study, we use per capita household income of less than $20,000 (under US Census 2000) as the threshold for poverty.

Knowledge of low-income issues in floodplain management is spotty. Repeated flooding resulting from hurricanes striking North Carolina, and most recently Hurricanes Katrina and Rita, has raised concerns that vulnerable low-income communities may be more exposed to the devastating costs of flooding. This issue has been covered in the popular press but to date has received only modest attention in the academic literature. Shilling et al. (1989) and Browne and Hoyt (2000) evaluated insurance penetration for low income inhabitants.

This section evaluates how residential flood losses in Census Blocks in SFHAs vary with mean resident income. In particular, using Census Block data on property values, income brackets, and demographic information coupled with flood loss estimates, we determine whether residential flood damages differ across ethnic and income groups, including for those living under poverty.

The analysis reveals two interesting results. First, those in the highest income brackets (household incomes larger than $75,000) are more prone to live in higher flood hazard areas (perhaps, we suspect, because they want a water view or easy access to a beach). These households can afford the premium from flood insurance. Second, low income households with incomes between $10,000 and $30,000 live in higher risk areas than the middle income households with incomes between $30,000 and $75,000. Presumably, low income households live in hazardous areas in order to find affordable housing or because they work in water recreation areas and find the least expensive housing nearby. The analysis also estimates the impact of urbanization (population), race, and number of rental units on flood damages at the Census Block level.

6.1. Data

To evaluate how well floodplain management protects low-income inhabitants of SFHAs, we use the HAZUS-HM Flood Model. The simulation model estimates direct economic losses to residences under different types of flooding and different community characteristics. In addition to the flood loss calculated by the engineering model of flood damage for each Census Block, we also have information on the mean property value, income, and demographic data for each Census Block.

Economic losses in the flood model are built from actual geographical data extracted from Geographic Information System (GIS) maps. HAZUS contains a hydrologic model of the United States. This model builds on the U.S. Geologic Survey (USGS) EROS 30-meter digital elevation model, gauge records, USGS regressions for ungauged reaches, National Oceanic and Atmospheric Administration (NOAA) data, and the hydrologic derivatives. Census data at the block level are merged onto the geo-coded database. Guided by U.S. Department of Energy building characteristics survey data, residence characteristics are estimated. Starting from the NFIP loss database, the model examines losses in known flood events, infers total losses by cost category (essentially residence and contents), then uses these to drive an engine for estimating losses by flood size. HAZUS stores most data at the Census Block level, with the ability to aggregate blocks into counties or other reasonable units.

Our analysis uses flood losses extracted from flooded Census Blocks under a 100-year flood (covering a population of 35,000) selected from 20 communities with special flood hazards areas (SFHA) across the United States. The number of observations was limited because of the lengthy HAZUS running time required to upload a community's information to simulate economic losses. (Details on the selection criterion are presented in Section 5.5).

6.2. Econometric Analysis

The econometric analysis uses Census Block data to explain how the characteristics of communities and residents affect the losses from flooding in SFHAs. In the analysis, we use HAZUS to simulate a water overflow of a 100-year flood, which results in the inundation of various Census Blocks. From the resultant flood levels in each Census Block, we determine economic losses for those in poverty, as well as other income groups. We also account for the population of each Census Block, number of rental units, and mean income and property values at each Census Block. From the available data, we formulate a fixed-effects model of flood losses:

$$F_{js} = a + r_j + \mathbf{C}_s\beta_1 + \mathbf{Y}_{js}\,\beta_2 + \mathbf{P}_{js}\,\beta_3 + \xi_{js} \qquad (1)$$

where flood damages (flood damage under a 100-year flood) in Census Block s at region j are F_{js}; the vector $\mathbf{C_s}$ codes each community with an indicator variable; and the vector $\mathbf{Y}_{js}$ shows for each Census Block the number of households in each income bracket (including those in poverty). The vector $\mathbf{P}_{js}$ includes for each Census Block the population and number of household units, as well as the number of rental units, mean income, and property values. The econometric residual ξ_{js} captures prediction error in the econometric model.

Dummy (indicator) variables for each community account for fixed (or non-random) differences in flood damages across communities. Similarly, the variance of the econometric residual ξ_{js} is likely to differ across communities. Heterogeneity from random effects is captured by the assumption:

$$\mathrm{Var}(\xi_{js}) = a + \mathbf{C}_s\beta^* + u_{js}$$

Table 16 and Appendix Tables A-1 and A-2 show coefficient estimates under different estimators. Table 16 shows estimates with both fixed and random effects. That means it accounts for variation between communities and controlling for community effects, between individuals within communities. Appendix Table A-1 shows coefficient estimates without fixed or random effects. Appendix Table A-2 shows the estimation with fixed community effects only.

For readers interested in the technical aspects of the statistical analysis, inspection of Table 16 shows that the existence of fixed effects for community heterogeneity is significant. This explains the anomalous result in Appendix Table A-1 (which excludes heterogeneity) that the more costly residences experience lower flood damages. Furthermore, Table 16 shows that random effects for community heterogeneity are likewise important in explaining flood damages. Comparisons of the tables reveal some sensitivity of results to the choice of estimator. Estimation results in the text refer to Table 16 because it correctly depicts the relationship between community characteristics and flood losses per residence in the SFHA.

6.3. Results

Two fundamental principles for evaluating a federal program are overall cost effectiveness and equity. A shortcoming for evaluating flood losses by income is that costlier residences by definition have a larger potential damage (e.g., larger replacement value). Consequently, to measure the NFIP's impact on equity, potential flood damage needs to be standardized by the value of property. As a result, we included value of property in the regression. Table 16 obtains the expected result that damages increase with the value of property.

Table 16 shows statistical correlations between flood damages and number of households and population in each Census Block. Not surprisingly, total losses rise as the number of households living in the block rises. Losses also rise as the number of rental units in the block rise. The table also shows that flood damages differ by ethnic composition of the block, with minorities, especially African American minorities, suffering the largest losses. Losses are greatest in blocks where relatively low income or upper income households live.

TABLE 16: Generalized Least Squares Regression with Fixed and Random Effects Estimating What Community Characteristics Influence Flood Losses in the SFHA During a 100-Year Flood

Variable	Estimate	Standard Error	t Value
Households	29.33	7.57	3.88*
Population	-6.41	1.84	-3.49*
African American	42.10	3.89	10.81*
Hispanic	3.54	2.34	1.51
Income < $10K	-136.03	20.06	-6.78*
Income $10to20K	44.57	16.67	2.67*
Income $20to30K	57.22	20.33	2.81*
Income $30to40K	-98.25	23.46	-4.19*
Income $40to50K	-72.01	27.52	-2.62*
Income $50to60K	-42.79	29.91	-1.43
Income $60to75K	43.89	27.78	1.58
Income $75to100K	198.10	26.92	7.36*
Income > $100K	36.24	13.13	2.76*
Average Housing Value	9.98E-07	2.46E-07	4.05*
Rental Units	43.08	21.21	2.03*
Mean Income	-1.1E-06	8.05E-07	-1.41
F-value for Existence of Random Effects	10.14*		

NOTE: The asterisk indicates statistical significance at the 95% confidence level. The random effects test only includes random effects for two communities.

6.3.1. Flood Loss and Census Block Characteristics

Results in Table 16 show that the rise in flood damages with number of residences (households) in the Census Block is statistically significant at the 95 percent significance level. Therefore, urbanization increases damage per residence after factoring out differences due to the price of the property. The reason for this difference is unclear.

Freeman (2002) shows general physical deficiencies in residences are larger for renters than homeowners. As a result, health risks from residential hazards are higher for renters and low income groups. Estimation results in Table 16 show that Census Blocks with more renters also have larger flood losses. The association of renter units with higher flood losses may indicate that renter residences were built pre-FIRM and may not have been built above the BFE. It also may relate to losses in beachfront investment property. This result is troubling since renters are not subject to the mandatory purchase provision of flood insurance, which requires that property owners carry flood insurance to qualify for a mortgage loan in SFHAs that can be sold into the secondary mortgage market. Insurance mandates thus miss the household contents of more vulnerable populations (renters).

6.3.2. Flood Loss across Income Groups

The distribution of population by flood hazard levels at the Census Block level provides a measure of NFIP adequacy to serve low income inhabitants. Results in Table 16 account for property values and other factors and thus evaluate the impact of poverty (household income of less that $20,000) on flood hazards. Households in extreme poverty (household income less that $10,000) have lower flood damages than any other income group. Yet, the majority of the population in poverty (household income between $10,000 and $20,000) suffer greater flood damage impact than middle class households with incomes between $30,000 and $75,000. Low income households above the poverty rate (income between $20,000 and $30,000) also have larger flood losses than the middle income families (income between $30,000 and $75,000). Higher income families with incomes of $75,000 (or larger) also face larger flood hazards than middle income families.

The analysis reveals two interesting patterns. First, higher income households who we suspect often live in high risk areas because they want water views or access to beaches and can afford flood insurance, face larger flood hazards. Second, low income households live in higher risk areas than middle income households, presumably in order to find affordable housing, especially housing near low-paying service job opportunities in water recreation areas.

Therefore, the poor and rich are more exposed to flood hazards than middle income households. This is a public policy issue because the poor are less likely to recover from economic losses. These shortcomings are accentuated by the fact that the poor generally lack flood insurance, and flood disaster relief is generally confined to $25,000. Moreover, the SBA rejected 70% - 85% of disaster relief loan applications in both the Great Mississippi flood and Hurricane Katrina, claiming applicant assets and income were too low to provide reasonable assurance of repayment (*Sharing the Challenge* 1994).

6.3.3. Race and Flood Hazards

Perhaps one of the most controversial issues is whether certain ethnic groups are exposed to larger hazards. Results in Table 18 show that, in controlling for incomes, African Americans suffer more flood damages on average than other races. This result suggests that African Americans are more exposed to flood hazards.

6.4. Analysis and Conclusions

It has been well documented that low income households confront larger flood-related risks than the average household. Hurricane Katrina highlighted the potentially devastating effects of flooding, ranging from extensive loss of life to total loss of assets. This paper explored the relation of poverty and flood risk in a stratified sample of SFHAs. The analysis included 3,500 Census Blocks and 35,000 people.

Analyzing the block-level data showed that the population with incomes of $10,000 to $30,000 are more exposed to flood hazards than those in other income groups (excluding those in the highest income brackets). The population in poverty is disproportionately living in areas of high flood risk, possibly because of economic opportunities (e.g., jobs at hotels) or because of marginalization into high-risk areas of older flood-prone housing.

Low income households presumably choose to live in hazardous conditions because hazardous housing is more affordable. This is a significant public policy issue because low income homeowners store almost all their wealth in their home investment. If that investment is destroyed, they are unlikely to recover from the economic losses.[27] Moreover, low income homeowners generally cannot afford – and therefore lack – flood insurance. Their flood disaster relief generally is confined to temporary housing assistance plus $25,000 in grant assistance with assistance payouts typically not exceeding $4,000 (Bea 1997).

Households that can afford upscale living with water views or water recreation access are also exposed to large flood hazards. The severity of flood damage thus follows a bi-modal distribution with respect to income.

[27] See http://www.huduser.org/publications/HOMEOWN/WAccuNHomeOwn.html

7. EVALUATION OF THE CONSEQUENCES OF FLOODS FOR LOCAL ECONOMIES AND GOVERNMENTS

A shortcoming of our financial analysis of floods is that HAZUS does not capture impacts on such financial outcomes as bond ratings and local government finances. The HAZUS analysis also does not capture the effects of floods in relation to the local municipal economy. This section compiles a list of the outcomes/impacts for analysis and the data sources containing the outcome data to determine the financial effects of floods on local government finances, bond ratings, employment and personal transfers. The results underscore the extent of the damages of floods beyond residential flood damages.

This section directly estimates the effect of flood events on local economic activity, personal transfers to individuals, local government finances, and bond ratings. Rather than examining an extraordinary flood disaster such as Hurricane Katrina, which paralyzed the Gulf Coast New Orleans for several months, we examine the impact of all flood events that caused property damages across all 1,200 communities with finance data reported in the *Statistical Abstract of the United States*. This provides a broader picture of the reaction of local economies to flooding.

7.1. Flooding and Local Government Finances

Local governments play a crucial role in community development with direct impacts on the health of the national economy (Tiebout,1956; Guiso et al., 2004; De Mello, 2002). These governments provide education, health and safety to communities across the United States, and they participate in environmental management. Jasanoff and Martello (2004) describe the variety of environmental-governance approaches that balance the local and the global management of resources as well as the frameworks of environmental governance retained by local communities.

Tiebout (1956) originally explored the economic foundations and the uniqueness of the functionality of local governments, and Saunders et al. (1967) first estimated the factors that influence local government finances. By mandate, the aim of local governments is to manage public goods (education, safety, health) to maximize social welfare in the community subject to a budget constraint. Revenues of local governments stem principally from property and sales taxes, while expenses stem from the provision of public service and the payment of debt service. Under intergovernmental programs, local governments also are entitled to receive transfers of funds from the state and the federal government.

Local governments manage permits for construction in cities (Jasanoff and Martello, 2004). Presently, an important related role of local governments is the management of preventive measures against the damages of natural hazards. Hutton and Mileti (1979) described the NFIP as the most extensive federal effort to encourage local jurisdictions to regulate floodplains.

Here, we use an economic model of local governance and estimate a system of equations of local government finances in terms of community characteristics. The analysis probes economic and environmental factors that affect inflow transfers and outlays by local governments. The econometric analysis tests the effect on local government finances of flood hazard levels. We consider the expected annual value of flood losses. The expected value of a random event is the same whether the actual flood occurs or not. We also consider the estimated loss after an actual flood event of selected sizes.

Results show the relation of flood risk and local government finances as well as the reaction of local governments to actual flood related events. The results yield insights into the actual operation of local governments and the consequences of natural hazards on public finances.

7.1.1. Local Public Finance Model

The mandate of local governments is to provide and manage certain public goods that contribute to maximizing public welfare in the community. The aim of local governments is to provide public services and goods, which economic models commonly notate as P, that maximize community welfare subject to the budget constraint. To supply P, the government must incur operational expenses, which are paid primarily from own revenues, R, collected at the local government level (e.g., local taxes).[28] This source of revenues is supplemented by transfers, T, that local governments receive from the federal and state governments. If local taxes and inter-governmental revenues do not cover expenses, local governments may need to increase their outstanding debt, D. Local government finances may depend on both structural characteristics (e.g., per capita income) and unexpected events (e.g., floods).

The level of public service, P, is directly related to local government expenditures, E. The provision of public services defined in terms of public welfare to the community is:

$$W = W[(P(E), R)|\psi] \qquad (1)$$

where public welfare, W, increases with the provision of P and decreases with the local government collection of funds from the municipality, R (e.g., taxation). Moreover, the welfare function depends on local characteristics of the community, ψ.

Local government's mandate to maximize the welfare of the community in Equation (1) is constrained by the budget of the municipality. This budget depends on the operational expenses paid through local taxes, municipal debt, and inflow transfers. Inflow transfers to local governments stem from intergovernmental revenues that consist of transfers from the state and federal governments. Ultimately, local governments control transfers because they must apply for these funds,[29] but qualifications for these applications depend on structural characteristics (e.g., per capita income), and matching a fraction of the cost.

In the welfare optimization, the local government control variables (E, R, D, and T) are a function of the exogenous variables (characteristics of the municipality ψ) in the model (see Mas-Collel et al., 1996).[30] Therefore, the system of equations that embeds the budget of local government finances is:

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[28] These revenues exclude inflow transfers from the state and the Federal governments.
[29] Jack (2005) also shows that in order to accrue transfers, local government may signal their status by measuring spending.
[30] From optimization theory, control variables in the optimization are only a function of the exogenous variables in the optimization.

$$\mathbf{GV = GV(\psi)} \qquad (2)$$

where

$$GV(\psi) = \{R(\psi), E(\psi), D(\psi), T(\psi))$$

The type of inflow transfers for which local governments may qualify in Equation (2) depends partly on whether the source is the federal or state government. Federal inflow transfers mainly stem from the Community Development Block Grant (CDBG) program that provides annual grants to cities and urban counties through what is referred to as its entitlement component. The program also allocates funds, by formula, to states, which distribute the funds among smaller and more rural communities, called non-entitlement areas, typically through a competitive process. In general, CDBG funds must be used to aid low- and moderate-income households, eliminate slums and blight, or meet emergency needs. Furthermore, the main source of transfers from the state to local governments stems from public welfare policies that respond to the needs of the community. State and Federal transfers to local governments, as a result, depend on the community characteristics:

$$T = \{T_s(\psi), T_f(\psi)\} \qquad (3)$$

where T_s and T_f are inflow transfers from the state and Federal governments, respectively.

The budget of local governments is thus represented in Equations (2) and (3), and the system of equations captures the reaction functions by local governments in the provision of public services. Characteristics of the community in the public finance model include per capita income Y_j, urbanization U_j, poverty rate V_j, typology of the local economy in terms whether the main sector is manufacturing M_j or services S_j, population Pop_j, percentage community growth G_j, and location L_j.

In addition to the economic conditions of the communities, natural hazards are sources of disruption to local government finances. For example, local government finances in Equation 2 may be affected by flood risk π_j and by actual flood events F_j. Finances of local governments are likely stressed after an emergency or natural disaster declaration in the municipality, floods are the most frequent and expensive natural disaster in the United States.[31]

7.1.2. Data and Estimation

The analysis of local government finances uses survey data available from the *Statistical Abstract of the United States 2002*. This statistical abstract reports local government expenses, transfer payments from the state and federal governments to local governments, local government debt, and general revenues for approximately 1,200 communities in 1997 and 1999. These financial data were merged with county economic indicators available from the *Bureau of Economic Analysis*. Information on economic typology (main sector in the economy) at each municipality was extracted from the *U.S. Census*. From this source, we also obtained a *U.S.*

[31] Ninety percent of all natural disasters in the United States involve flooding (*Insurance Information Institute, March 2005).*

Census urbanization indicator by municipality. Small values of the urbanization index indicate large metropolitan areas, whereas high numbers code rural areas (low urbanization).[32]

TABLE 17: Variable Definitions and Mean Values Averaged Across Observations for 1997 and 1999

Variable	Definition	Mean
E_j – Spending (millions dollars)	Total government spending this year	$1051
R_j – Local Revenue (millions dollars)	Local government revenue this year from all sources	$690
T_{sj} – State Transfers (millions dollars)	Local government revenue this year from state government	$265.9
T_{fj} – Federal Transfers (millions dollars)	Local government revenue this year from the Federal government	$20.2
D_j – Debt (millions dollars)	Local government debt at the end of this year	$1043
L_{j1} – Latitude	Latitude of the locality	38.41
L_{j2} – Longitude	Longitude of the locality	90.36
Y_j – Per Capita Income (dollars)	Mean per capita income in the locality this year	$22,628
Pop_j – Population	Population of the locality this year	116,569
G_j – Income Growth	Change in per capita income from two years earlier	0.32
π_j – Flood Risk	Average NFIP premium in the community, net of subsidies	435
F_j – Flooded This Year	0-1 variable, set to 1 if the locality experienced a flood this year according to National Weather Service data	0.18
F_{j-1} – Flooded Last Year	0-1 variable, set to 1 if the locality experienced a flood last year	0.24
M_j – Manufacturing = Main Economic Sector	0-1 variable, set to 1 if manufacturing is the main economic sector in the locality	0.35
S_j – Services = Main Economic Sector	0-1 variable, set to 1 if services is the main economic sector in the locality	0.16
H_j – Farming = Main Economic Sector	0-1 variable, set to 1 if farming is the main economic sector in the locality	0.03
U_j – Urbanization	Census Bureau urbanization index (the lower the value, the greater the urbanization)	3.76
V_j – Poverty Rate	Percent of the local population living in poverty this year	12.76
E_j – Fraction with College Education	Percent of adult residents who completed college	0.32
ER_j – Earnings per worker	Mean earnings per worker this year	$24,796

NOTE: F_j and F_{j-1} capture indicator variables for floods that caused damages to residences in the current year and the previous year.

Indicators of flood hazards for each municipality were extracted from *National Weather Service* (NWS) and *National Flood Insurance Program* (NFIP) data. The NWS annually reports communities suffering economic losses from floods and storms. Floods that affected residences

[32] The urbanization indicator ranks municipalities with respect to urbanization in categories. The first category, for example, includes municipalities located in metropolitan areas with populations of 1 million or more; a mid-range urban area in the ranking has an urban population of 20,000 or more, but not adjacent to a metropolitan area; and the category for least urbanization is a completely rural or less than 2,500 urban population, not adjacent to a metropolitan area.

in the community were identified and coded as an indicator variable (a variable that takes on a value of zero or one). Only qualitative information indicating that flood damages occurred could be coded because reported damages are aggregated across all municipalities with damages in a flood event. (i.e., NWS estimates of flood damages are not broken down by community). Data on the average flood risk of each community was extracted from the NFIP average premium in each community. Table 17 presents the mean values of the available data for the 1,200 reported communities.

From the available data and the economic model in Equation (2), a statistical model of local public finances can be estimated. Specifically, the classical panel regression model for the economic model in Equation (2) is:

$$\mathbf{GV}_{jt} = \boldsymbol{A} + \mathbf{B}\psi_{jt} + \tau_t + \xi_{jt} \tag{4}$$

where the variable τ is a fixed effect for the time period t; the vector of explanatory variables is

$$\psi_j = \lfloor Y_j \;\; Pop_j \;\; G_j \;\; L_j \;\; \pi_j \;\; F_j \, F_{jt-1} \;\; U_j \;\; V_j \;\; M_j \;\; S_j \rfloor' \; ;$$

and the correlation of the econometric residual between equations k and i of the local government financial system of equations is:

$$\mathrm{Cov}(\xi_{jk}, \xi_{ji}) = \sigma_{ki}$$

The system of equations in the statistical model thus allows for correlation across the components of local government finances (see Greene, 2003).[33]

Summary statistics of the variables used in estimation are reported in Table 17. Table 18 reports the Generalized Least Squares (GLS) coefficient estimates of the system of equations describing local government finances. Coefficient estimates that can be defined in terms of elasticities are presented in Table 19.[34] Analysis of responsiveness of local government finances to community characteristics will refer to the elasticity estimates in Table 19, while analysis of statistical significance will refer to t-values reported in Table 18.

The econometric analysis tests the effect on local government finances of flood hazard levels. After factoring out the effect of actual flood events in the previous two years, the analysis shows whether local governments in areas with larger expected flood hazards (flood risk) operate differently. We also estimated the reaction of local governments to flood occurrences. Actual flood events show the aftermath of a natural disaster on local government spending, revenues,

[33] With the available data, a generalized least squares (GLS) estimator of (4) is a consistent and asymptotically efficient estimator. The estimator uses fixed effects (indicator variables) to account for heterogeneity for the two years of the sample, and the estimator filters out the serial correlation across equations, i.e., $\sigma_{ki} = E(\xi_{jk}\xi_{ji})$. Consequently, coefficient estimates are found by applying the GLS estimator, i.e., Zellner's estimator (see Greene, 2003), for cross-equation residual correlation.

[34] An elasticity is a unit free measure of response. For example, the elasticity of variable y with respect to variable x refers to the percentage change in variable y caused by a one percent change of variable x.

and debt levels. The results yield insights into the actual operation of local governments and the consequences of natural hazards on public finances. (Sensitivity analysis showed that the results are unaffected by addition of variables that account for regional variation.)

TABLE 18: Estimates of the System of Equations Describing Local Government Finances

Equation/Variables	Expenditures (t-value)	Local Revenues (t-value)	Federal Transfers (t-value)	State Transfers (t-value)	Debt (t-value)
L_{j1} – Latitude	-15.37* (-3.36)	-17.74* (-5.72)	-0.35 (-1.45)	3.51 (1.69)	-47.74* (-9.06)
L_{j2} – Longitude	-5.82* (-3.77)	-5.57* (-5.33)	-0.85* (-10.64)	-0.61 (-0.87)	-6.69* (-3.77)
Y_j – Per Capita Income	0.04* (7.07)	0.02* (6.35)	0.001* (2.08)	0.01* (5.02)	0.004 (0.72)
G_j – Income Growth	-707.8* (-4.05)	-370.72* (-3.13)	-28.37* (-3.12)	-245.68* (-3.10)	-478.70* (-2.38)
π_j – Flood Risk	-0.08 (-0.75)	-0.13* (-2.14)	-0.005 (-0.84)	0.070 (1.47)	-0.179* (-2.48)
F_j – Flooded This Year	-130.39* (-2.79)	-27.61 (-0.87)	-5.94* (-2.44)	-90.73* (-4.27)	141.69* (2.63)
F_{j-1} – Flooded Last Year	-27.25 (-0.64)	-5.86 (-0.20)	6.28* (2.23)	-29.31^x (-1.52)	128.47* (2.62)
M_j – Manufacturing = Main Economic Sector	-11.39 (-0.28)	-70.36* (-2.52)	5.59* (2.60)	48.06* (2.57)	-122.31* (-2.58)
U_j – Urbanization	-16.64 (-1.60)	-7.59 (-1.07)	-0.12 (-0.21)	-13.65* (-2.89)	-0.36 (-0.03)
V_j – Poverty Rate	3.92 (0.85)	-2.75 (-0.88)	0.16 (0.68)	7.41* (3.53)	-14.19* (-2.66)
S_j –Services = Main Economic Sector	124.65* (2.25)	105.84* (2.82)	4.29^x (1.49)	-4.75 (-0.19)	263.68* (4.13)
Pop_j – Population	0.005* (33.89)	0.003* (31.50)	0.0002* (19.03)	0.001* (21.38)	0.004* (23.26)

Note: F_j and F_{j-1} capture indicator variables for floods that caused damages to residences in the current year and the previous year. Indicator variables introduce statistically significant fixed effects for each of the two years in the sample. See Table 17 for variable definitions.

* = significant at the 95% confidence level
^{x} = significant at the 85% confidence level

TABLE 19: Elasticity Estimates of Selected Variables of the System of Equations Describing Local Government Finances

Equation/Variables	Expenditures	Local Revenues	Federal Transfers	State Transfers	Debt
Y_j – Per Capita Income	0.82*	0.76	0.64*	1.05*	0.1
G_j – Income Growth	-0.22*	-0.17*	-0.44*	-0.3*	-0.15*
π_j – Flood Risk	-0.03	-0.08*	-0.1	0.11	-0.07*
V_j – Poverty Rate	0.05	-0.05	0.1	0.36*	-0.17*
Pop_j – Population	0.58*	0.56*	0.86*	0.66*	0.46*

NOTE: Asterisks indicate statistical significance at the 95 percent confidence level.

7.1.3. Impact Analysis

The Impact of Flood Risk on Government Finances

Table 18 shows that flood hazards are significantly and negatively correlated with debt outstanding in the community. Controlling for other factors (e.g., actual flood occurrences in the last two years, income, population), local governments in municipalities with larger flood hazards have less debt. Local governments confronting larger uncertainties from natural hazards also maintain lower debt obligations. Table 19 shows that a 1 percent increase in the flood risk is associated with a 0.07 percent lower debt level. A municipality with twice the risk of flooding is predicted to hold 7 percent less debt.

Flood hazards are also associated with significantly lower local revenues. We suspect that flood hazards induce a price discount in property values, which decreases property taxes, the main source of revenues to local governments. In contrast, flood risk and local government spending levels are not significantly associated at the 95 percent confidence level. The probability associated with flood hazards in a county furthermore has little statistical relationship with inter-governmental revenues.[35] The local government's reaction to flood risk is likely to differ from their response to actual flooding. By definition, mitigation represents preparedness to face risk, and flood events force clean-up and prompt additional protective action.

The Impact of Floods on Government Finances

Local government finances are likely to be strained after a flood. The expenditure estimates in Table 18 show that local government expenses are temporarily depressed after flood events (the coefficient for flooded this year in the expenditure equation is negative and statistically significant at the 95 percent confidence level). Floods also alter revenue flows from intergovernmental sources. The econometric model indicates that revenues from both federal and state programs are depressed in the year a flood occurs. Federal transfers decline by 29 percent and state transfers by 34 percent, resulting in a $97 million revenue decline. This may happen because service delivery that generates state revenues is disrupted after the flood or because local government involvement in post-flood activities during the year a flood occurs consumes resources normally used for writing grant applications. Conversely, the year after a flood, federal transfers rise significantly, with the local government recouping the $6 million in federal transfer

[35] Intergovernmental revenues differ from local government own source of revenues (e.g. local taxes).

payments that it lost the previous year (from the coefficient of flooded last year in the federal transfer equation). State revenues only partially recover in the year following the flood, however, remaining almost $30 million (11 percent) below pre-flood levels, but this difference only is significant at the 85% confidence level.

In the event of a disaster, local governments may be entitled to subsidized loans from the federal government to pay for local infrastructure repair (The Robert T. Stafford *Disaster Relief and Emergency Assistance Act*, Public Law 93-288). From Table 20, the coefficient of the debt equation on the variable “flooded this year” (F_j) is positive. Hence, flood events cause affected municipalities to incur more debt. Therefore, while the community at high flood risk but no recent floods holds lower debt, an actual flood is associated with an increase in debt. Flooding, as a result, forces local governments to increase their outstanding debt to fund recovery and maintain public services. This underscores the tendency of local governments to defer payments on recovery costs, covering them with years of future local taxes. From Table 20, federal transfers to local governments increase in the period after the flood, but the rise is small relative to the additional debt local governments have to incur.

Therefore, while the community subject to flood hazards holds lower debt, the actual event of a flood increases the debt holdings. The sensitivity of debt to actual flood events, moreover, illustrates that a possible consequence of flood events is lower ratings for bonds issued by the municipality, which could have long term implications for the costs of credit.

7.1.4. Conclusion

We use an econometric model of local government finances to estimate local government response to economic conditions and natural hazards. From the economic model of local government finances, we estimated a system of equations of government finances. The empirical analysis derives the impact of flood risk and the impact of actual flood events.

The empirical analysis shows that floods disrupt local government spending and sources of intergovernmental revenues and cause affected municipalities to incur more debt. The level of expenditures recovers the year after the flood, but debt levels continue to increase a year after the flood. Federal transfers to local governments increase in the period after the flood, but the rise is small relative to the additional debt local governments have to incur. A consequence of flooding, therefore, is that local governments increase their outstanding debt to fund recovery and maintain public services in their communities. The increase in debt is five times larger than receipts from federal relief aid after a flood. Interestingly, flood risk and floods are associated with opposite effects on the local government debt position. Municipalities with larger risk maintain smaller debt, which might be explained in part by the larger financial risk associated with natural hazards.

7.2. The Effect of Flood Events on Municipal Bond Ratings

The HAZUS simulation analysis in Sections 4 to 6 illuminates issues concerning the costs and consequences of flooding. Those sections use a simulation model to determine the impact of the NFIP and the different levels of insurance penetration on the costs of flooding and on their distribution among payers. The analysis in these sections, however, ignores the impact of flooding on local economies and local governments. Section 8.1 models local governance and estimates a system of equations of local government finances in terms of community characteristics. Those results find that local government finances are stressed after a flood. Financial stress caused by flood events increases local government expenses and increases debt. Section 8.2 captures the effects of floods on the cost of credit.

7.2.1. Municipal Bond Ratings

To borrow resources needed for capital investment, communities often issue bonds to the public. The yield of the bond depends on the current prime rate and on the risk of default of the debt. Standard & Poor's Ratings Service, for example, extracts information on risk for investors in municipal bonds. A Standard and Poor's rating is an opinion on the creditworthiness of the municipality. The rating is not a recommendation to purchase or sell, but rather a recommendation on credit suitability to the investor. The main component of the rating is the municipality capacity to pay its obligations. An obligation rated "AAA" has the highest rating assigned in Standard and Poor's. A rating of "AA" only differs from "AAA" to a small degree with the municipality's capacity to pay the bond still very high. Nevertheless, the community will pay a higher interest rate when it issues bonds. An obligation of "A" is more susceptible to changes of circumstances and economic conditions, and a rating of "BBB" is even more susceptible to changes of those conditions. Bond ratings lower than "BBB" are considered as speculative investment, junk bonds.

Bond ratings are likely to be explained by structural characteristics of the community (e.g., *per capita* income), as well as regional events that impose financial stress on local governments. Finances of local governments are likely to be stressed after an emergency or natural disaster declaration within the municipality; floods are the most frequent and expensive natural disaster in the United States.[36] The financial impact of floods on municipalities may extend beyond direct damages if flood losses induce an increase in the cost of credit to local governments. The cost of credit may have long-term consequences in the afflicted municipalities. This section examines whether bond ratings are lower in municipalities that experienced flood damages.

To measure the determinants of bond ratings, we specify an ordered discrete choice model with the Standard and Poor's rating of the municipality as the dependent variable. This rating depends on the economic and financial circumstances of the municipality. The risk on debt acquired by a local government is related to its outstanding debt D; the annual revenues the local government collects from local taxes R; and transfers from the center to the local government T.[37] We hypothesize that the solvency of local governments also depends on municipal *per capita* income Y, urbanization U, poverty rate V, economic growth G, and population P. In addition to structural characteristics (e.g., per capita income), bond ratings may be affected by unexpected events (e.g., floods F).

The composition of the local economy (e.g., farming, manufacturing, service sectors) also contributes to the risks related to earnings in the community, which introduces uncertainty to local government revenues. We code municipalities on whether the main sector of the local economy is farming H, manufacturing M, or service S. Geographical coordinates (Latitude L_{1j} and longitude L_{2j}) capture intrinsic heterogeneity in explaining ratings. To estimate the effects of

[36] Ninety percent of all natural disasters in the United States involve flooding, according to the National Flood Insurance Program (*Insurance Information Institute, March 2005)*.
[37] These transfers refer to intergovernmental revenues received from the state and Federal government.

floods on bond ratings, we use the maximum likelihood estimator solved using the Gauss-Newton algorithm (see Greene, 2003; Maddala, 1996).

7.2.2. Data

To estimate the factors that determine municipal bond ratings, this section uses Standard & Poor's bond ratings of 380 communities that issued debt and that had local government finance data in the *Statistical Abstract of the United States 2002*. The financial data include transfers from state/federal government to local governments, local government debt, and general revenues from local taxes. Economic indicators for each of these communities were extracted from the US Bureau of Regional Analysis (Department of Commerce). These include local per capita income and population, and local economic growth in the last five years. Information on economic typology (code of the municipality with respect to its main economic sector) at each municipality was extracted from the U.S. Census. From this source, we also obtain a U.S. Census urbanization indicator by municipality. Small values of the urbanization index indicate large metropolitan areas, whereas high numbers code rural areas (low urbanization).[38]

Indicators of actual flood events for each municipality were extracted from the National Weather Service (NWS) data. The NWS annually reports which communities suffered economic losses from floods. The impact of floods that affected residences in the community is identified and indexed as an indicator variable. We include flood events that caused property damage exceeding $500,000 and that occur both in the year of and year prior to the issuance of the bond. Only qualitative information indicating that flood damages occurred could be coded because reported damages are aggregated across municipalities with damages in a flood event.

[38] The urbanization indicator ranks municipalities with respect to urbanization in categories. The first category, for example, includes municipalities in metro areas of 1 million population or more; a mid-range urban area in the ranking has an urban population of 20,000 or more, but not adjacent to a metro area; and the category for least urbanization is a completely rural or less than 2,500 urban population, not adjacent to a metro area.

TABLE 20: Maximum Likelihood Estimates of the Ordered Logistic Regression Showing the Relationship of Bond Ratings to Recent Flooding, Community Characteristics, and Community Finances

Equation/Variables	ML Estimator	
	Coefficient Estimate	t-value
Constant	5.860**	2.31
Y_j – Per Capita Income	0.068*	1.67
D_j – Debt	-0.004	-1.57
R_j – Total Revenue	0.013**	3.39
T_j – Federal + State Transfer Payments	-0.013**	-2.84
P_j – Population	0.009**	4.20
G_j – Income Growth	-0.553	-0.19
U_j – Urbanization	-0.246*	-1.90
M_j – Manufacturing = Main Economic Sector	-0.220	-0.64
S_j – Services = Main Economic Sector	3.562**	2.46
H_j – Farming = Main Economic Sector	-1.135*	-1.72
V_j – % in Poverty	-0.199**	-3.72
L_{1j} – Latitude	-0.141**	-3.40
L_{2j} – Longitude	-0.008	-0.69
F_j – Flooded in Past Two Years	-0.740*	-1.92

NOTE: The asterisk indicates statistical significance at the 90 percent confidence level, and double asterisk indicate significant at the 95 percent confidence level. See Table 17 for variable definitions.

7.2.3. Statistical Results

A natural hazard may increase vulnerability of finances of local governments. Point estimates (numerical value) in Table 20 show that communities that experienced flood events have lower bond ratings, and the qualitative result is statistically significant at the 90 percent confidence level. Two possible explanations are (1) that regions more prone to flood events are correlated with other community characteristics that contribute to lower ratings and (2) flooding decreases ratings. By factoring in community characteristics that might affect ratings in the ordered logit model, the probability of the first explanation appears limited. For that reason, we conclude that financial distress from flooding appears to reduce bond ratings of local governments, which increases the cost and reduces availability of credit to local governments.

The financial effect of floods on municipalities thus may extend beyond direct damages to an increased cost of credit. The cost of credit may have long-term consequences in the afflicted municipalities. For example, flood events may deter municipal investment in new projects that may have long-term implications in the growth and health of communities.

The next section shows the impact of flooding on local employment and personal transfers to individuals.

7.3. The Impact of Flood Hazards on Local Employment and Personal Transfers to Individuals

Industry productivity and employment may be affected by natural hazards. The severity and nature of the impact of a disaster depend on a range of factors. These include the type of hazard, the size of the economy, and the sectors affected by the disaster. For example, droughts do not damage buildings or physical structures, but sudden-onset disasters such as floods or earthquakes have a direct impact on infrastructure and productive facilities and resources. This section directly estimates the effect of flood events on local economic activity and personal transfers to individuals.[39]

7.3.1. Effect of Floods on Local Employment

To formulate an econometric specification of municipal employment, we model employment E_j in region j in terms of regional comparative advantages $\mathbf{C_j}$, the economic and financial characteristics of the municipality $\mathbf{X_j}$, and local earnings per worker ER_j. Employment may also depend on disruptions to the local economy from floods $\mathbf{F}$.

Mathematically, the statistical model of employment at municipality j is:

$$\ln E_j = a + d \ln ER_j + \mathbf{C}_j\boldsymbol{\beta_1} + \mathbf{X}_j \boldsymbol{\beta_2} + \mathbf{F}_j \boldsymbol{\beta_3} + \xi_j$$

where employment E_j at region j depends on $\mathbf{C_j}$ and $\mathbf{X_j}$, as well as local earnings per worker ER_j. The vector $\mathbf{X}_j$ comprises population P_j and the level of urbanization in the county U_j. This vector also includes municipal taxes T_j, debt D_j, and local population with a college education, CE_j. The vector $\mathbf{C}_j$ comprises codes of the county with respect to the main economic sector. We code whether the main sector is farming H_j, manufacturing M_j, or service S_j, respectively. The vector $\mathbf{C}_j$ also comprises geographical features captured by the county's geographical latitude L_{1j} and longitude L_{2j}. The vector $\mathbf{F}_j$ contains codes of floods that cause residential damage during the year of the flood, F_j, or the previous year, F_{j-1}. The econometric residual, ξ_j, captures other factors not captured in the model.

In addition to the characteristics of the county, as explanators of employment, we include community distance and earnings per worker relative to others, ER_{-j} (see Sarmiento and Wilson, 2005):

$$\ln E_j = a + d \ln ER_j + \mathbf{C}_j\boldsymbol{\beta_1} + \mathbf{X}_j \boldsymbol{\beta_2} + \mathbf{F}_j \boldsymbol{\beta_3} + \rho \ln ER_{-j} + \xi_j \qquad (5)$$

Estimation of Equation (5) yields insights into the actual operation of local economies and the consequences of natural hazards on local employment. All non-qualitative variables in Equation (6) are defined in logarithms.

[39] These personal transfers are different from the impact of flood hazards on transfers to local governments discussed in Section 8.1.

Estimation and Results

To include heterogeneity in equation 5, the non-linear least squares estimator of equation 5 incorporates both fixed and random effects with respect to each county's Bureau of Economic Analysis (BEA) region. Table 21 gives the regression results, showing the effects of regional variables on total employment**.**

Controlling for other factors, Table 21 shows that floods reduce employment (significant at the 95 percent confidence level). For example, under the average unemployment rate of 5 percent, a flood event that damages property would increase local unemployment to 8.2 percent. The employment decrease for the average flood is 3.4 percent.

Analysis of lagged effects shows that the effect of floods on employment does not persist beyond one year. Losses of economic activity are concentrated in the year of the flood; on average, the level of employment recovers one year after the flood. Employment losses caused by the flood in the year of the flood, however, constitute a permanent loss in expected accumulated wealth levels at both the individual and community level. This loss of wealth potentially has a substantial effect on community welfare.

This section pinpointed the effects of flood events on local economic activity. It showed statistically that floods disrupt employment in municipalities affected by floods. Employment levels, however, recover after one year. Unemployment benefits presumably will increase as employment falls. Next we analyze how floods affect personal transfer payments

TABLE 21: Regression Showing the Relationship of Local Employment Levels to Flood Events and Community Characteristics

Variable	Coefficient Estimates	t-value
Constant	-1.995	-10.723
Lat – Latitude	0.003	0.640
Long – Longitude	0.002	1.309
Latitude x Longitude	0.000	0.031
Time Fixed Effects	0.041	7.303
R_j – Local Revenue	-0.001	-0.205
D_j – Debt	-0.004	-3.292
P_j – Population	0.901	67.959
E_j – % with College Education	0.070	6.160
U_j – Urbanization Index	-0.032	-10.255
F_j –Farming = Main Economic Sector	0.007	0.365
M_j –Manufacturing = Main Economic Sector	-0.008	-1.170
S_j –Services = Main Economic Sector	0.050	5.834
F_j – Flooded This Year	-0.034	-3.595
F_{j-1} – Flooded Last Year	-0.001	-0.210
ER_j – Earnings per worker	0.616	72.294
ER_{-j} – Earnings in Nearby Localities	-0.002	-3.350

NOTE: None of the coefficient estimates that would capture differences in per capita spending between Bureau of Economic Analysis (BEA) regions are statistically significant. See Table 17 for variable definitions.

7.3.2. Effect of Floods on Personal Transfers

Personal transfers to individuals include federal assistance relief, insurance benefits, and federal aid for the poor and disadvantaged (e.g., unemployment benefits and Medicaid). Moreover, by law, flood events trigger increases in personal transfers (that compensate economic disruption from floods) through federal relief aid. Under the Stafford Act, a disaster declaration triggers federal aid to victims in the form of loans, grants, and tax breaks. Individuals may qualify for Small Business Administration (SBA) loans (i.e., federally subsidized loans) to repair and replace homes and property that sustain damages not covered by insurance. In case the individual fails to qualify for a SBA loan, the individual may alternatively qualify for individual assistance grants under the Individuals and Household Program (IHP). IHP grants provide money and services to cover individuals' losses that the victims are unable to pay through other means (e.g., insurance, loans).

Personal transfers also capture NFIP insurance payments, a main source of relief for flood losses. Flooding may also increase transfers in the form of unemployment benefits and

Medicaid. We evaluate statistically the proportional change in personal transfers from a flood. Mathematically, the statistical model of personal transfers at municipality j is:

$$\ln PE_j = a_2 + \mathbf{C}_j\beta_{12} + F\mathbf{X}_j\,\beta_{22} + e_2\mathbf{F} + d_2\,ER_j + \rho_2 ER_{-j,p} + \xi_{j2} \qquad (6)$$

where the vector $\mathbf{TX}_j$ include variables of $\mathbf{X}_j$ in (5), as well as per capita income Y_j and poverty rates PR_j**.** The econometric residual ξ_{j2} captures other factors not captured in the model. All non-qualitative variables in Equation (6) are defined in logarithms.

Table 22 shows the effects of regional variables on personal transfers to individuals**.** Flood effects on personal transfers stem from federal insurance payments, federal relief aid, unemployment benefits, Medicaid, and other safety net payments. Table 22 shows that personal transfers increase on average by 3 percent after a flood event. The effect of these transfers, however, lasts only one year. The lagged effect of floods on transfers, while positive, is not statistically significant at the 95 percent confidence level, consistent with the lack of a lingering effect of floods on employment.

7.3.3. Conclusion

The previous sections demonstrated the implications of flooding and floodplain management on individuals and public finance. Sections 4 to 7 measured losses by controlling for flood size and insurance penetration. The HAZUS analysis, however, did not provide information on the effect of floods on local government finances, bond ratings, and employment. Section 8.1 showed that floods cause local governments to increase debt, while local government expenses and intergovernmental revenues are disrupted. This section shows impact of floods on employment and personal transfers. Our research in this section pinpointed the effects of flood events on local economic activity and on transfers to individuals.

We show statistically that floods disrupt employment in municipalities affected by floods. Flood events decrease employment on average by 3.4%. Employment levels, however, recover after one year. Unemployment benefits presumably will increase as employment falls, and many floods will bring federal relief. Numerically, the estimated increase in personal transfers is 3%. Disruption of employment implies loss of wealth to affected residences and businesses.

TABLE 22: Regression Showing the Relationship of Personal Transfers to Flood Events and Community Characteristics

Variable	Coefficient Estimates	t-value
Constant	3.174	4.230
Lat – Latitude	0.005	0.546
Long – Longitude	0.009	2.708
Lat x Long	0.000	0.097
Time Fixed Effects	-0.064	-5.965
R_j – Local Revenue	-0.012	-1.542
D_j – Debt	0.000	-0.226
P_j – Population	1.108	38.565
Y_j – Income	-0.219	-3.667
PR_j – Poverty Rate	0.250	13.263
E_j – % with a College Education	-0.154	-5.952
U_j – Urbanization Index	0.005	0.638
F_j –Farming = Main Economic Sector	-0.016	-0.484
M_j –Manufacturing = Main Economic Sector	0.010	0.797
S_j –Services = Main Economic Sector	0.098	6.299
F_j – Flooded This Year	0.038	3.017
F_{j-1} – Flooded Last Year	0.013	1.158
ER_j – Earnings	0.230	14.443
$ER_{-j,n}$ – Earnings in Nearby Localities	-0.007	-5.840

NOTE: Coefficient estimate that capture Bureau of Economic Analysis (BEA) region are not statistical significant with the exception of the Far West Regions that receives significantly larger personal transfers. See Table 17 for variable definitions.

8. CONCLUSIONS & RECOMMENDATIONS

This study confirms that the insurance and floodplain management elements of the NFIP reduce costs to government and individuals and prevent uncompensated losses. It shows that the NFIP does not provide a strong economic incentive to develop in the floodplain. More importantly, its subsidy for older residences below BFE probably discourages redevelopment of the residences most at risk of flood losses.

The HAZUS simulations show that the NFIP mitigation requirements prevent substantial costs to households and government in the aggregate. The study is limited in that on the one hand it did not evaluate the costs of mitigation in housing construction, but on the other hand it also did not include the considerable social and non-economic costs of floods and disrupted lives, exposed clearly in the wake of the 2005 flood events. Other research confirms the strong value of mitigation projects generally,[40] showing mitigation costs will be less than the flood losses that HAZUS suggests will be averted.

NFIP insurance coverage modestly reduces costs to government and considerably reduces uncompensated flood losses to individuals. These findings emphasize the desirability of high insurance penetration within the SFHA. In addition, the average value of the reduction in uncompensated losses associated with insurance coverage adds so little to property values that it seems implausible that the NFIP creates considerable development pressure. The subsidy of pre-FIRM properties through discounted insurance premiums, however, is likely to have slowed rebuilding of this housing stock above BFE. Rebuilding would yield significant mitigation cost savings from the government's perspective.

Flooding affects communities more broadly than HAZUS is able to measure. Flood impacts not captured in HAZUS include that bond ratings fall, raising the cost of municipal borrowing, employment declines for one year, municipal spending declines, and municipal debt rises. Further, our study and HAZUS both "ignore impacts on people including lives lost and people displaced, family trauma and social disruption, loss of items like family photos that cannot be replaced, business interruptions, disruption of government services, tourism reductions, and shortages of critical human services. Indirect environmental costs also can arise, e.g., the costs if a sewer line breaks polluting a bay, or the loss of an erosion-buffering beach or wetland that may alter the future vulnerability of the community." (David et al. 1999). Thus HAZUS analyzes only the most readily measurable subset of the total costs of flooding.

The costliest part of this study was design and model building. Follow-up research building on the existing design would be relatively inexpensive and should be undertaken. When the 2010 Census is released, its structure inventory should be loaded into HAZUS, along with other updates, and our analysis should be updated. The update should reassess the annual cost savings resulting from flood insurance and related mitigation efforts, savings to government, and the impact on development costs in the SFHA.

We also recommend experimenting with a further set of HAZUS estimates that it may be appropriate to run annually in order to better document and publicize the savings to society and to government that result from NFIP-induced mitigation and from flood insurance sales. These

[40] Research indicates that the benefits return on investment in such flood mitigation projects is four dollars for every dollar spent (Multihazard Mitigation Council, 2005, p. 149)

estimates would cover all floods that were declared as disasters, plus any other floods above a selected size or damage threshold that were not confined to sparsely populated areas.[41]

It also would be desirable to look more deeply at a sample of flooded communities in order to explore the nature of the employment and government expenditure shifts that occur. Average shift size and duration tell only part of the story. Case studies probing the full range of flood-related costs and consequences for floods of different frequencies also would be informative.

[41] An initial simulation would produce a damage estimate that should resemble actual damages, allowing verification that the model reproduced reality reasonably well. Estimate quality probably will be better across the portfolio of the year's floods than it is for any individual flood. Additional simulations should be run to estimate what damages and government costs would have been if no NFIP-induced mitigation had occurred and at if flood insurance penetration had differed from actuality.

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TABLE A-1: Ordinary Least Squares Regression Estimating What Community Characteristics Influence Flood Losses in the SFHA During a 100-Year Flood

Variable	Estimate	Standard Error	t Value
Intercept	512.90	264.69	1.94
Households	10.73	9.62	1.12
Population	-4.30	2.29	-1.87
African American	35.90	3.90	9.2*
Hispanic	3.65	2.57	1.42
Income < $10K	-187.44	25.26	-7.42*
Income $10-20K	87.80	21.25	4.13*
Income $20-30K	121.82	25.80	4.72*
Income $30-40K	-158.24	28.28	-5.6*
Income $40-50K	-4.85	30.96	-0.16
Income $50-60K	-89.17	36.00	-2.48*
Income $60-75K	53.05	34.64	1.53
Income $75-100K	132.36	32.45	4.08*
Income > $100K	111.16	16.39	6.78*
Average House Value	-0.0042	0.0007	-5.79*
Rental Units	109.32	22.67	4.82*
Mean Income	0.012	0.005	2.52*

NOTE: The asterisk indicates statistical significance at the 95% confidence level.

TABLE A-2: Ordinary Least Squares Regression with Fixed Effects Estimating What Community Characteristics Influence Flood Losses in the SFHA During a 100-Year Flood

Variable	Estimate	Error Standard	t Value
Households	4.21	9.37	0.45
Population	-5.20	2.30	-2.27*
African American	34.45	4.08	8.43*
Hispanic	4.38	2.69	1.63
Income < $10K	-169.48	25.00	-6.78*
Income $10-20K	93.21	20.78	4.49*
Income $20-30K	117.75	25.14	4.68*
Income $30-40K	-141.51	27.75	-5.1*
Income $40-50K	5.61	30.15	0.19
Income $50-60K	-60.52	35.26	-1.72
Income $60-75K	81.58	34.14	2.39*
Income $75-100K	137.55	32.28	4.26*
Income > $100K	104.24	16.19	6.44*
Average House Value	0.003	0.001	2.34*
Rental Units	143.61	22.90	6.27*
Mean Income	0.0009	0.0050	0.19
F-value for Existence of Fixed Effects	14.57*		

NOTE: The asterisk indicates statistical significance at the 95% confidence level.

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