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Improving Flood Insurance and Flood Risk Management

Insights from St. Louis, Missouri

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RESOURCES FOR THE FUTURE

Improving Flood Insurance and Flood Risk Management: Insights from St. Louis, Missouri

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Abstract

This paper examines the history of St. Louis, Missouri in coping with flood risk over the past 15 years, with a focus on flood insurance. Six challenges to the continued management of riverine flood risk are identified and discussed. They are (1) many property owners don't buy flood insurance, (2) people underestimate flood risk, (3) we need better flood maps, (4) we have a "love affair" with levees, (5) flood risk is increasing over time, and (6) we take deep pride in rebuilding after a disaster. Recommendations for how to improve flood risk management in light of these challenges are offered. Focused attention is given to the possibility of long-term flood insurance contracts tied to long-term loans for risk-mitigating activities in overcoming the six challenges.

Key Words: disaster insurance, National Flood Insurance Program, risk, floods

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1. Introduction

The costs of natural disasters, both worldwide and in the United States, have grown substantially in recent years (Kunreuther and Rose 2004; Cutter and Emrich 2005; Munich Re 2005). Of all natural disasters over the last century in the United States, floods claimed more lives and led to more property damage than any other (Perry 2000). Figure 1 highlights the steep increase by decade in the total direct costs of flood events in the United States since the 1930s. Further, many climate models predict that in a warming world, extreme precipitation and flood events are likely to increase in many parts of the country (Allan and Soden 2008; U.S. Climate Change Science Program 2008). These changes require a close look at the management of flood risk in this country and how it can be improved. While Hurricane Katrina focused national attention on hurricane risk and the impact of storm surge on property, there is a need to also carefully examine inland flooding on rivers, lakes, and streams.

St. Louis, Missouri, no stranger to flood risk, provides a case example for investigating the current challenges of managing riverine flood risk in the United States. St. Louis City and County (St. Louis City is independent and functions as its own county) are located just below the confluence of two of the mightiest rivers in the country: the Missouri and the Mississippi. The St. Louis area is almost entirely within the triangle formed by these two rivers and the Meramec River. Numerous creeks and streams crisscross the region. Figure 2 shows the city and county, their rivers, and FEMA-mapped floodplains.

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The most devastating flood in recent memory was the 1993 flood on the Missouri and Mississippi Rivers, which ravaged not just St. Louis, but most of the upper Midwest. The National Oceanic and Atmospheric Association estimates that 20 million acres in nine states were flooded, with damage estimates ranging from $12 to $16 billion (GAO 1995). The risk to the St. Louis region was highlighted as recently as September 2008, however, when a heavy storm swelled the River Des Peres and other creeks, damaging many homes and taking two lives. FEMA paid around $8 million in grants to Missouri in response to the September flooding.

This paper examines the history of St. Louis in coping with flood risk over the past two decades, with an emphasis on the role of flood insurance. Detailed data on flood insurance policies-in-force and claims from the 1993 flood were examined, as were Geographic Information System data on the spatial extent of flood risk vis-à-vis parcels in St. Louis County. From this detailed case analysis, we identify six challenges to continued management of riverine flood risk:

1) Many property owners don't buy flood insurance.
2) People underestimate flood risk.
3) We need better flood maps.
4) We have a "love affair" with levees.
5) Flood risk is increasing over time.
6) We take deep pride in rebuilding after a disaster.

The next section of the paper briefly reviews the National Flood Insurance Program (NFIP), since much of our discussion focuses on the operation of this program and how it can be improved. Section 3 discusses each of the six challenges in turn and offers policy suggestions on how to address them. In Section 4, we detail one possible solution to addressing all of these challenges: long-term flood insurance contracts coupled with long-term loans that would encourage investment in risk-reducing measures. Section 5 provides concluding comments.

2. Brief Overview of the National Flood Insurance Program

The NFIP was created in 1968 in response to the claim by private insurers that flood peril is uninsurable. The insurers argued that adverse selection would be a problem with only those in high hazard areas purchasing coverage, that risk-based premiums would be higher than any homeowner would be willing to pay, and that enough premiums could not be collected to cover the most catastrophic flood events (Overman 1957; Anderson 1974). A government program might be successful since it could pool risks more broadly, have funds to jumpstart the program, subsidize homeowners currently residing in hazard-prone areas, and tie insurance to land use regulations and building codes that would lower risks (Grossman 1958).

The NFIP, part of the Federal Emergency Management Agency (FEMA), was designed as a partnership between the federal government and local communities. In exchange for homeowners and businesses being able to purchase flood insurance, local governments adopt a minimum set of floodplain management policies. These may include, for example, that new buildings be elevated or otherwise protected from flood damage. Anyone may purchase insurance once a community joins the NFIP, although coverage is limited to $250,000 for residential buildings and $100,000 for residential contents and limited to $500,000 each for nonresidential building and contents coverage. Currently, almost 20,000 communities participate in the program; as of August 2008, there were over 5.5 million policies-in-force nationwide. The vast majority of these flood policies are written by private insurance companies that keep a portion of the premium to cover their operating and administrative expenses, but the risk is borne entirely by the federal government.

To set premiums, FEMA divides participating communities into varying flood-risk "zones" that are displayed on Flood Insurance Rate Maps (FIRMs). Premiums are set for each zone nationwide (GAO 2008). They do not vary by region or community, but only by flood zone and characteristics of the property, such as its height above the base flood elevation. To make program implementation feasible, properties in place before a community was mapped, so-called pre-FIRM properties, receive subsidized rates, both to encourage communities to join the program and to not penalize homeowners who had built in the floodplain without knowing the risk, and who would otherwise face high rates and a decline in property values (Pasterick 1998). It was thought the subsidy would phase out quickly as houses were damaged or improved,[1] but around a quarter of all properties are still subsidized, since modern construction techniques have extended the life of buildings (Pasterick 1998; Wetmore et al. 2006; CBO 2007). The total amount of the subsidy has decreased over time, however, as FEMA raised rates on these properties between 1981 and 1995.

Despite the perception at the time the NFIP was created that simply the availability of flood insurance would lead those at risk to purchase it, take-up rates for flood insurance have historically been quite low. Tropical Storm Agnes, in 1972, resulted in more disaster assistance being paid by the federal government than any previous storm, because only a few of the affected communities had joined the NFIP and very few properties that suffered damage were

[1] Subsidized properties only become required to pay actuarial rates when they are damaged at half the property value or when improvements increase their value by 50 percent or more (CBO 2007).

insured (FEMA Federal Insurance and Mitigation Division 2002). By the end of 1973, fewer than 3,000 out of 21,000 flood-prone communities nationwide had entered the NFIP and less than 275,000 policies had been sold to homeowners in these areas (Kunreuther 1978). This slow beginning led Congress to pass the Flood Disaster Protection Act of 1973 (PL 93-235), which made flood insurance mandatory on any mortgage from a federally insured or regulated lender for any property located in a 100-year floodplain.

Twenty years later, the 1993 Missouri and Mississippi River floods showed once again, however, that take-up rates remained shockingly low. Only about 10 percent of structures damaged in the 1993 flood were insured (The American Institutes for Research 2005). Congress responded in 1994 with the National Flood Insurance Reform Act, tightening sanctions on lenders in an effort to increase compliance and spur higher take-up rates. The Act created financial penalties for noncompliant lenders, made clear that lenders were not absolved of liability if the loan was sold or transferred, and mandated that lenders purchase insurance on behalf of the borrower if the borrower failed to do so. The extent to which these new regulations have affected lender compliance or take-up rates remains unclear, although the number of NFIP policies-in-force nationwide has grown steadily since the late 1980s.

3. Six Challenges for Flood Risk Management from St. Louis, Missouri

For this study, NFIP policy and claims data for St. Louis County were analyzed.[2] A detailed policy database for the years 2000 to 2005 provided information on the type of policy, amount of coverage purchased, premium paid, flood zone, and census tract (addresses were removed due to privacy concerns). A claims database spanning the 1993 flood contained non-identifying information, such as the date of loss, amount of damage, and how much was paid. Summary data on all policies-in-force for the years 1978 to 2007 were also examined. In addition, a parcel-level Geographic Information System file from the St. Louis County Planning Department was combined with Q3 data from FEMA on the extent of floodplains in the St. Louis area. This allowed for some spatial analysis of the flood risk. Finally, an exhaustive review of local area newspapers, NGO reports, and the relevant academic literature was undertaken. Six specific challenges to the management of inland flood risk emerged from this detailed case analysis of the St. Louis area. Each will be discussed in turn.

[2] We would like to thank Ed Pasterick and Tim Scoville for providing the NFIP policy and claims data.

3.1 Many Property Owners Don't Buy Flood Insurance.

Flood insurance can lower the social costs of flood events by reducing the amount of federal relief payments. On average, the NFIP estimates that every $3 paid in claims reduces federal disaster assistance spending by $1.[3] The NFIP also claims that flood damages are reduced by nearly $1 billion each year due to the purchase of policies and community regulations required by the program. A recent study of NFIP costs based on FEMA's HAZUS model and an analysis of historical data concluded that under the most likely assumptions, the NFIP has reduced the cost of federal disaster assistance annually by $527 million, a reduction of likely 61 percent, although each home located in a 100-year floodplain still costs taxpayers between $48 and $125 each year (Sarmiento and Miller 2006). There is a second reason insurance purchases can lower the social costs of disasters. If federal relief covers the costs of flood events, homeowners get the benefits of their location choice but do not have to shoulder all of the costs, which theoretically could lead to an overinvestment in risky locations (Krutilla 1966). If homeowners had to pay more of the costs of locating in a risky area through the purchase of insurance, more efficient location decisions would presumably be made.

In St. Louis County, however, very few homeowners purchase flood insurance. Figure 3 shows the number of policies-in-force in the county at the end of each year from 1978 through 2007. There is a clear jump in 1993, the year of the devastating flood; however, at least some of this increase can be explained by individuals purchasing insurance when they saw the flood warnings in the days before the crests from the Missouri and Mississippi Rivers hit St. Louis. In 1993, property owners could purchase a NFIP policy and have it go into effect in a matter of days, which allowed them to avoid years of premium payments and still file a claim if the warnings proved accurate. This loophole has since been closed. There is now a 30-day waiting period before a NFIP policy takes effect.

While 1,620 more policies were in force at the end of 1993 compared with 1992, it is impossible to say what fraction of these were purchased by individuals exploiting the earlier loophole in the NFIP. Out of those claims filed in 1993 or 1994, 143 were on policies with an effective date sometime in June 1993 and 343 were for policies with an effective date sometime in July 1993. This suggests that at a lower limit, perhaps a third of the increase in policies-in-force resulted from those joining the NFIP when the threat was imminent.

[3] This claim is made on the NFIP's website, but no supporting analysis is given.

Comparing the number of NFIP policies-in-force for the years 2000–2005 with the total number of properties in St. Louis County, in and out of the floodplain, highlights the low take-up rates. In 2000, only around 1 percent of all single-family homes in St. Louis County had NFIP insurance. If the sample is restricted to those homes in a 100-year floodplain, where the mandatory purchase requirement applies and the risk is greatest, the take-up rate is closer to 15 percent. This is still lower than the 20 percent take-up rate for flood insurance in the Midwest recently reported by the RAND Corporation (Dixon et al. 2006). The RAND study finds that take-up rates in the Midwest, however, were the lowest in the country (although the report cautions about a small sample size); in contrast, rates in the south and west were closer to 60 percent.

This finding of lower take-up rates in the Midwest is echoed by the observation that NFIP policies are highly concentrated geographically. Around 40 percent of all NFIP policies are in just one state—Florida—and close to 70 percent are in five states: Florida, Texas, Louisiana, California, and New Jersey (Michel-Kerjan and Kousky 2008). Of course, these numbers are not normalized for the number of people located in risky areas in each of these states. While there is no national database of the number of people located in floodplains, statewide take-up rates can be determined by dividing the number of NFIP policies-in-force as of September 30, 2007, by the U.S. Census 2006 estimate of population for each state. With this measure, Florida is still in the lead with an overall take-up rate of just over 12 percent. Although Texas has the second highest number of NFIP policies-in-force, its take-up rate is below 3 percent, while Missouri's is actually around 4 percent. Louisiana—third in absolute policy numbers—has a take-up rate that is a close second to Florida at just under 12 percent.

It is unclear why take-up rates should be comparatively lower in areas not subject to coastal flooding. Several hypotheses could explain this behavior, some of which are suggested by Dixon et al. (2006). Coastal residents may be more informed about the risk of hurricane damage than inland residents are about riverine risk or coastal residents may be more risk averse regarding hurricanes, leading more Gulf residents to insure. Perhaps the risk is more salient, causing homeowners to take more protective actions. This could be due to the availability heuristic, whereby the perceived probability of a future event is impacted by the ease with which individuals can recollect it (Tversky and Kahneman 1973).

It could also be that damages from hurricanes are more severe or that the variance of losses from hurricane-related flood damage is greater than river-related flood damage and this leads more people to insure in coastal areas. Potentially contrary to this seemingly plausible explanation, yearly data from 1955 to 2003 show that the mean and standard deviation for flood

losses are greater for the state of Missouri than for the state of Florida.[4] (Hurricane damages from wind are not included in this comparison and wind damage is not covered by NFIP policies.) Louisiana, however, had a slightly higher mean and standard deviation over these years. This does not include the damages from Katrina, which would presumably exacerbate this finding.

It is also possible that certain features of the NFIP program make it unattractive to Midwest residents. For instance, NFIP policies exclude losses to basements (there are a few exceptions, such as pumps, washers, and dryers) and with many smaller floods in the St. Louis area just harming basements, this exclusion may make NFIP insurance less attractive. It could also be that NFIP insurance premiums are priced "too high" for the Midwest and "too low" for the coast. Premiums for NFIP insurance vary only by flood zone designation and house characteristics. While rates are higher for coastal zones subject to storm surge, it is unclear that the price is commensurate with the risk in these areas. It is also unclear if areas not subject to storm surge but in 100-year floodplains in coastal areas have the same expected losses as 100-year floodplains in the interior of the country. A Congressional Research Service (CRS) report put it this way: "The government generally finds it difficult to assess risk because of political pressure not to differentiate one person or firm from another the way the private sector would. This difficulty might lead to large and hidden cross-subsidies" (King 2008). If Midwestern homeowners perceive that the rates are higher than their expected losses, they are unlikely to insure.

The NFIP should consider adhering to the following simple principle discussed in a recent study on catastrophic risks (Kunreuther and Michel-Kerjan 2009): *Premiums should reflect risk.* Insurance premiums based on risk provide signals to individuals as to the magnitude of the risk they face and encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes. Without this principle, premiums do not send accurate signals of the risk and cross-subsidization of various sorts will likely occur.

More research is needed to untangle the possible causes of the lower take-up rates in the Midwest and thus what the proper policy response should be. If they are due to cross-subsidization in the premiums, rates could be adjusted to reflect expected losses for counties as

[4] Data from a reanalysis of National Weather Service data (Pielke et al. 2002). Available online at: http://www.flooddamagedata.org.

opposed to the nation as a whole; this practice is already in effect for federal crop insurance.[5] Such a change would make the program more closely adhere to the principle of having premiums reflect risk. The basement exclusion could be eliminated if it is found to deter purchase of insurance, even if the coverage would need to be offered at a higher price given the greater probability of a loss. If Midwesterners are found to have different risk information or different attitudes toward risk than coastal dwellers, the reasons for this should be investigated to see if targeted information campaigns or other interventions could help reduce the discrepancy.

Despite differences across the country, estimates of take-up rates in 100-year floodplains are consistently low. Whether this is due to a failure to enforce the mandatory purchase requirement at the time of loan origination or a failure to ensure that property owners maintain coverage for the life of the loan is unknown. Mortgages are bought and sold, and even if a policy is purchased when the loan is originated, the homeowner may later drop the coverage. In one estimate, less than one-tenth of homeowners keep their policy beyond one to three years (Kunreuther and White 1994). It could also be that homeowners in high-risk areas are obtaining loans from unregulated lenders or do not have a loan at all and are not voluntarily insuring. Conclusive data on this topic, however, are lacking (GAO 2006).

Low take-up rates in St. Louis County seem to be a combination of failure to insure initially and failure to retain policies. Out of all the policies-in-force in the year 2000, less than one-third were still in force in 2006 (Kousky 2008). However, given that only an estimated 86.4 percent of residents of St. Louis County are in the same house they were in a year ago,[6] we should only expect 41.6 percent of policies that were in-force in 2000 to still be in-force in 2006. It thus seems likely that the larger problem—at least in St. Louis County—is getting individuals to insure initially. Some of this may be due to lack of compliance with the mandatory purchase requirement, but there are also many homeowners in risky areas either without a mortgage or with a mortgage from an unregulated lender that is not subject to the mandatory purchase requirement.

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[5] Crop insurance premiums are determined by county and by crop. For more details on crop insurance pricing, see: www.casact.org/education/ratesem/2004/handouts/worth.ppt

[6] Estimate taken from the American Community Survey 3-Year Estimates for 2005–2007.

3.2 People Underestimate Flood Risk

Behavioral economics research has shown that individuals often dismiss low-probability events, misunderstand the risk-spreading function of insurance, and are overly optimistic about whether they will be the victim of a disaster (e.g., Kunreuther and Slovic 1978; Camerer and Kunreuther 1989). Research has also demonstrated that individuals often do not accurately understand the concept of probability and regularly have little idea of the magnitude of the disaster risks to which they are exposed. When homeowners in areas at risk for floods, for example, are asked to estimate the chances of a severe event occurring, answers vary widely. Informal discussions in 2006 between one of the authors and a handful of business owners and residents in Chesterfield Valley, an area in the Missouri River floodplain of St. Louis County, revealed this with estimates of the annual probability of a flood ranging from zero to 20 percent. All these individuals had property in 100-year or 500-year floodplains where the annual probability estimated by FEMA is 1 or .2 percent. There also appears to be little connection between probability estimates and insurance decisions; many of the respondents to a 1978 survey who substantially underestimated the risk had insurance, while others who substantially overestimated the risk had none (Kunreuther 1979).

There is a particular problem with the way probabilistic information on flood risk is communicated to residents. Flood risk is often discussed in terms of the “x-year event,” such as the 100-year flood or the 500-year flood. A 100-year flood has a 1/100 or 1 percent chance of occurring in any given year. To put this in perspective, properties in a 100-year floodplain have a 26 percent chance of the property flooding at least once during a 30-year period. Anecdotal evidence from newspaper articles and other sources, however, suggests that many individuals misunderstand this risk, thinking that after a 100-year flood occurs, they are safe for another 100 years, instead of realizing that the term refers to a probability and that two “100-year” floods could occur in a row (Pielke 1999). Although the chances of having 100-year floods in two consecutive years is very low, the likelihood of having at least one more 100 year flood occurring during a 25 year period if one occurred last year is .22. Thinking one is safe for 100 years after a 100-yaer flood is essentially the gambler’s fallacy, or belief that the likelihood of an outcome falls after it has just occurred (the mistaken belief that a system has “memory”). Some residents of the St. Louis area have been shown to make this mistake, such as one man from Chesterfield, Missouri, who was quoted after the 1993 flood as saying: “This won’t happen again for another 100 years,” (Best and Linsalata 1993).

To address this perception problem, FEMA has begun referring to the 100-year flood as the 1 percent annual flood to stress the probabilistic nature of the term (Galloway et al. 2006). So

far this new language has not caught on among the public or other officials. A Google search found 341 hits for “1 percent annual flood” but 310,000 for “100-year flood.” A survey of engineers and floodplain managers found that they overwhelmingly disliked communication of flood risk in “x-year” terms and the majority thought the public would respond better to descriptive terms such as “high risk” or “moderate risk” (Galloway et al. 2006). It appears that adopting such a language change, however, is quite difficult. A long-term contract, as discussed in Section 4, may present information in a way that is more salient to property owners by communicating the likelihood of such a flood over a 20 or 25 year time period.

Further confusing home and business owners is the fact that only property owners in 100-year floodplains are told they are in a floodplain and are required (if they have a mortgage from a federally regulated lender) to purchase flood insurance. Some homeowners thus assume if they are not told they are in a 100-year floodplain, they are safe and do not need to purchase a policy. Floods can, and do, occur outside 100-year floodplains, but many seem to dismiss this risk. One property owner in St. Louis County received documents at closing indicating his property was not in a floodplain and yet in 1993, his property flooded, causing him to lose six months of income and forcing him to borrow $70,000 for repairs (Best and Linsalata 1993). Some homeowners, though, who reside outside the 100-year floodplain, do buy policies perhaps because they are better informed or are more risk averse. In St. Louis County, in the year 2000, close to 30 percent of policies-in-force were for properties outside of 100-year floodplains and 15 percent of all claims in St. Louis County between 1991 and 1996 were for properties outside 100-year floodplains.

In 2004, FEMA began a campaign called FloodSmart to try to correct public perception about flood risk. A website with comprehensive information on flood risk and flood insurance has been created and the campaign is running TV, print, radio, and online ads for flood insurance. A recurrent campaign message stresses that flood risk is not eliminated outside 100-year floodplains. One TV commercial, for instance, says “25 percent of all flood losses actually occur to homeowners with a low flood risk.” The extent to which this campaign will increase take-up rates among property owners is an open question.

3.3 We Need Better Flood Maps

The NFIP has an understandable administrative need for simple and clear risk designations, but the floodplain designations currently used obscure the fact that the 100-year floodplain does not have a bright line where risk changes abruptly. Risk varies continuously across the terrain, and these variations are not communicated effectively to property owners.

Furthermore, estimation of the 100-year floodplain is uncertain, both because data are limited and because changes in risk or modeling techniques may not have been incorporated yet into the floodplain delineation. One line on a map does not portray this uncertainty.

It is thus not surprising that many individuals seem to respond to flood risk as being binary. More specifically, nationwide, there is an apparent increase in development just outside the 100-year floodplain line and many properties are elevated just to the 100-year standard, creating a large amount of exposure nationally for flood risks between the 1 and .2 percent standards (Galloway et al. 2006). It is difficult to determine the extent to which this might have occurred in St. Louis. When claims filed in 1993 and 1994 for St. Louis County are examined by flood zone, there are a greater number of larger claims in the 500-year floodplain than in the 100-year floodplain, suggesting either higher property values and/or more damaging floods outside 100-year floodplains (see Figure 4). For the most part, this seems to be due to higher commercial claims in 500-year floodplains. The average claim in 1993 and 1994 from St. Louis County for single-family residential properties was $15,231 in the 100-year floodplain and $17,390 in the 500-year floodplain. For commercial properties, these figures were $95,918 and $115,180, respectively. (For both residential and commercial properties, there are many more claims filed, as would be expected due to higher take-up rates, in 100-year floodplains).

Since most home and business owners get their information on flood risk from FEMA maps, conveying more accurate information on flood risk will be difficult without improving the maps. Around 75 percent of FEMA maps are over a decade old and are not updated frequently enough to incorporate increased development, new data, or new estimation techniques (FEMA Federal Insurance and Mitigation Division 2002). Given the changing nature of flood risk in many communities, including St. Louis County (discussed below), this can give homeowners a false sense of the flood risk. For example, Temple University researchers undertook a detailed analysis of the Pennypack Creek Watershed outside of Philadelphia, Pennsylvania, and found the 100-year floodplain was much greater in area than designated on the existing FEMA map (Center for Sustainable Communities 2006).

FEMA's ongoing map modernization program is attempting to update maps. While new maps will improve the accuracy of risk information, in many communities residents protest when the new designations put them in a higher risk area where flood insurance is required—especially if the community has not recently experienced an extreme flood event (e.g., Murray 2008). Residents are concerned about the costs of insurance and falling property values due to flood risk designations, but seem less concerned about the actual risk they face—perhaps an example of optimism bias, or the feeling that disasters "won't happen to me" (Camerer and Kunreuther

1989). For instance, when maps were updated in Hudson, Ohio, one man said it was "another way for the federal government to take money out of [his] pocket" (Freeman 2008).

Such sentiments are understandable in light of the finding that out of a random sample of 9,500 Fannie Mae loans, four companies used by lenders in determining on which properties were inside or outside a 100-year floodplain only agreed on less than one-third of the properties. (Tobin and Calfee 2005). Such confusion is problematic. Clearly, the precision and consistency of risk designations need to be significantly improved. In addition, risk designations, as well as map changes, need to be done in a more transparent manner, so they do not appear arbitrary to residents and are not subject to political manipulation.

3.4 We Have a "Love Affair" with Levees

It has been observed that the United States has a "love affair" with levees (Tobin 1995). Levee construction began on the Mississippi River in the 1700s. After the federal government became involved in flood control, levees were this country's primary response to flood risk through most of the 1900s. Levees in good condition effectively hold back flood waters for events below their design standard and are clearly one necessary part of flood risk management. Still, the full range of consequences from levee construction must be considered. One side-effect of levees is that they create a perceived safety that spurs development behind the levee. This so-called "levee effect" (Tobin 1995) means that when the levee fails, the resulting damages are many times more severe than had the induced development not occurred. This concept dates back to early work by Gilbert White (1945).

When development increases behind protective structures, the level of protection provided by government also increases in response to the new development. This interaction can create a situation in which there are increasing returns to an increase in either protection or development, creating multiple equilibria (Kousky et al. 2006). This dynamic between private development and government protection was noted by Kydland and Prescott (1977). They argued that if the socially optimal floodplain development policy is to protect existing development, but not allow new development, it may not be achieved by allowing individuals to make their own investment decisions. This is because developers know that if they locate in a risky area, the government will provide protection. In this case, it may be better to prohibit development. Kunreuther and Pauly (2006) use this logic coupled with misperceptions of the risk to make the case for mandatory disaster insurance.

This interaction between development and protection is clearly at work in the St. Louis metro area, where over $2 billion of new development has taken place in floodplains since 1993, much of it behind new levees (Jones 2005). The case of Chesterfield, one of over 90 municipalities that make up St. Louis County, is an interesting one. The Monarch Chesterfield Levee protecting the Missouri River floodplain of Chesterfield failed in 1993, flooding Chesterfield Valley to a depth of about 8 feet. By the spring of 1994, the U.S. Army Corps of Engineers had repaired the levee to pre-flood standards. But in the wake of the devastation, residents, business owners, and developers in the region began to lobby that the levee be upgraded to protect against a 500-year flood.

A rebuilding task force, with representatives of business interests, and a county advisory group composed mainly of developers, recommended both increased protection and increased development in Chesterfield Valley. Since waiting for U.S. Army Corps of Engineers' approval for the project would take years, delaying profitable development activities, Chesterfield, at the recommendation of developers, began building a private levee instead of waiting for a publicly financed one to be built for them. Tax-increment financing was used to raise the funds. In short, the city drew on state legislation that allowed them to designate the floodplain as a blighted district, eligible for redevelopment, and issue bonds to cover the costs of improving the area. Chesterfield could then amortize the debt by earmarking half the increase in sales and property tax to debt retirement. In 2000, however, the Corps gave its approval and is supplementing the levee construction with federal funds.

At the time of the 1993 flood, damage to the 250 businesses in the Valley was substantial, with estimates ranging from a quarter to half a billion dollars (Stelzer 2000). Between 1993 and 2002, the square feet of development in the Valley more than doubled to 6 million square feet (Heisler 2003a); between 1993 and 2005, over $400 million was invested in floodplain land (Hipple et al. 2005). The area now boasts of being home to the largest strip-mall in America, complete with a smorgasbord of big-box retail stores, restaurants, and a large movie theater. Should the levee fail again, damages would be many times more severe. The designer of the drainage system for Chesterfield Valley called this a "virtuous circle," whereby more protection in the form of levees leads to more development, which leads to more protection (personal communication). Others in the region do not see it that way. A member of the Sierra Club thought the interaction was troublesome: "They've been allowing the development to take place, which then gives them the justification for building the levee to protect that development. It's the cart before the horse," (Stelzer 2000).

Levees, however, are far from being failsafe. During the 1993 Mississippi River floods, close to 70 percent of the levees under stress failed (Tobin 1995).[7] Many homeowners believe levees provide complete protection, but in truth there is a "residual risk" in the areas behind levees that needs to be more effectively communicated to residents. Levees are only designed to protect against a certain magnitude flood, and if a more extreme event occurs, they can be overtopped or fail. Furthermore, many levees in this country are substandard and residents behind them may not be aware of this.

Despite the residual risk, if properties are protected by a certified 100-year levee, property owners are not required to purchase insurance, and if communities request it, FEMA will remove areas protected from certified 100-year levees from the flood maps (Shipley 2003a; Shipley 2003b; Pinter 2005). Individuals will then receive no warning about the risk. The *St. Louis Post-Dispatch* reported about one resident who learned about this aspect of the NFIP the hard way: "Kevin Corrigan even got a letter from his bank telling him he wasn't in the flood plain when he built a $1.6 million building in Chesterfield Valley just a month before it flooded," (Shipley 2003b) when the levee protecting the valley failed.

If a levee is not certifiable, however, FEMA will mark the area behind the levee as at risk and the mandatory purchase requirement will apply. Residents across the river from St. Louis City are experiencing this firsthand. Many of the levees protecting communities from Alton to Columbia, Illinois, are behind levees that are no longer certifiable and new flood maps will reflect this. Both policymakers and scholars have considered whether insurance should be mandatory behind levees, whether or not the levees are certified, given the disastrous consequences should they fail (Galloway et al. 2006). While there would likely be opposition to such an insurance requirement, it would signal the risk to property owners, and, if priced correctly, potentially lead to more efficient development decisions.

Another concern about levees is that while they protect the area behind them, they also increase flood stages upstream, accelerate the flow of water downstream, and push water onto neighboring communities. In the St. Louis area, so-called "levee wars" are occurring, whereby each community tries to have the highest levee (Missouri Coalition for the Environment Foundation 2003; Shipley 2003c). An investment by one municipality, however, increases the risk for its neighbors, leading to more and higher levees continually being built.

[7] Only 20 percent of the federally constructed levees failed.

Increases in levees are allowed under federal regulations as long as they do not increase flood heights by more than one foot. All these small changes add up, however, increasing flood heights, and the Corps of Engineers does not evaluate these cumulative effects. In Missouri, the state has no authority over the construction or modification of levees, of which there are currently about 1,450; the Corps works directly with the local governments (Shipley 2003c). This has led to a lack of overall planning in the region and the runaway levee wars. Some states, such as Illinois, Minnesota, and Wisconsin, require state approval for levee construction (Shipley 2003b). This might be a model other states should consider as a way to address the externalities levee construction generates.

3.5 Flood Risk is Increasing Over Time

Flood hazard in many regions is increasing over time, due primarily to three factors: development of watersheds, structural flood control projects, and climate change. These factors can lead to both a gradual increase in the mean flood height over time and/or the variability increasing, both of which would increase potential damages from flooding. When these changing conditions are neglected, decisions can be based on erroneously low estimates of the hazard. For policy decisions and investments that are difficult to adjust, such as development and construction of protective works, failing to consider changing conditions could potentially “lock in” suboptimal decisions.

3.5.1 Development

Development reduces the amount of pervious surface area in a region, leading to more runoff and thus exacerbating flooding. As more and more land is developed or drained, both the frequency of floods and the peak discharge can increase (Tobin 1995). A recent study of several communities subject to riverine flooding found that building in a watershed increases the flood risk and that managing this increase by regulating development or undertaking measures to address the increase in flood hazard can generate cost savings (Blais et al. 2006). Given that it takes FEMA many years to re-map communities, serious consideration should be given to incorporating projected increases in development into flood maps.

In the 10 years after the 1993 flood, new development occurred in floodplains of all Midwestern states, despite buy-out programs by FEMA to remove some properties from risky areas. Out of seven states examined, Missouri ranked first in new development and accounted for almost 78 percent of the total new floodplain development, with the majority occurring in the greater St. Louis metropolitan area (Hipple et al. 2005). In the St. Louis area, there is over $2.2

billion of new investments on land that was submerged during the 1993 flood (Pinter 2005), raising questions about the impact of development on runoff that could exacerbate flood problems. In places such as Chesterfield Valley, much of the new development is big-box retail, which usually comes with expansive parking lots that dramatically reduce pervious surface area. This can pose a problem for flood management in communities. Indeed, Wal-Mart settled a lawsuit in 2001 for $5.5 million in which it was charged with violating storm water discharge laws at a handful of stores (Irwin and Clark 2006).

In contrast to the growth in floodplain development seen around St. Louis, some communities have actively withdrawn from the floodplain. After 1993, FEMA and other federal government agencies spent hundreds of millions of dollars to remove frequently flooded property from the floodplain. In Missouri and Illinois alone, FEMA bought 7,700 properties at a cost of $56.3 million (Pinter 2005). In 2001, however, these efforts were minimized by the Bush administration, which sought to reduce federal funding for the conversion of floodplains to open space and failed to renew a program that restored farmland to wetlands—nature's natural flood control system (Jehl 2001).

Some communities in the greater St. Louis area have decided to more aggressively regulate floodplain development on their own; one is Arnold, Missouri (Best 1993). Arnold has strict land use regulations for the floodplain that establish allowable lot size, type of development, and how high structures must be raised above base flood level. In addition, Arnold pursued federal money to remove buildings from floodplains, restoring the land to a natural state. All of this has given them a 10 percent reduction in NFIP premiums through the Community Rating Program, which rewards communities with lower premiums for undertaking mitigating activities.

Another way to minimize flood problems from development is to base flood management around projected development. For instance, Maryland and Wisconsin require flood projects to consider what the risk will be when the drainage basin is fully developed (Shipley 2003c). Increases in runoff from development can be controlled with regulations that force developers to account for the increase through the construction of retention ponds or other methods. Another option is to restrict the amount of impervious surface area or impose a tax on development equal to its impervious surface area footprint and use the funds to better manage the runoff. Both Pasco County, Florida, and Boulder, Colorado, have taxes on impervious surface area, for example.

Seattle, Washington, has taken an innovative approach to storm water management by using natural areas to decrease runoff.[8] Another option is the use of pervious pavement that allows water to seep into the ground. In St. Louis, the College School in Webster Groves used this approach.

3.5.2 Structural Projects

The Missouri and Mississippi Rivers near St. Louis are no longer natural rivers. They have been straightened and narrowed, dams and levees have been built to hold back floodwaters, banks have been armored to reduce erosion, and wing dams have been installed to decrease sediment build up. Historic flood data for the Missouri and Mississippi Rivers near St. Louis show that flood stages have increased for large discharges of water and that this increase can be attributed to engineering works on the rivers (Belt 1975; Criss and Shock 2001; Pinter and Heine 2002). This means that for the same volume of water, the river is higher now than in the past. Data from the U.S. Geological Survey were used to plot these trends for the Missouri River at St. Louis in Figures 5a and 5b. As seen in Figure 5a, flood stages have been increasing over time. Most of this increase is attributable to higher stages for high volume events, as seen in Figure 5b where height is plotted against volume for two time periods.

Part of the problem is that the contribution of each structural project to flood heights is evaluated individually. Each project by itself may have a negligible impact on flood heights, but taken overall, the effect could be substantial (Pinter 2005). If these projects were evaluated for their cumulative impact, the costs could be weighed against the benefits. This would require examining projects from a basin-wide perspective.

3.5.3 Climate Change

A group of scientists proclaimed last year in the journal *Science* that because of anthropogenic climate change, “stationarity is dead” regarding water management (Milly et al. 2008). Evidence is mounting regarding an increase in flood risk in certain areas from a warmed world. Large flood events have increased in the last century, a link has been established between higher temperatures and more heavy rain events, and climate models predict increases in both the frequency and magnitude of heavy precipitation in the United States (Milly et al. 2002; Galloway

[8] More information is available on their website at: http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/index.asp.

et al. 2006; Allan and Soden 2008; U.S. Climate Change Science Program 2008). In addition, for coastal areas, sea level rise will exacerbate flood risk. A report issued by the Environmental Protection Agency on January 15, 2009 estimated that the annual sea level rise on the East Coast of the U.S. from New York to North Carolina will be between 2.4 and 4.4 millimeters.[9]

Instead of reacting incrementally and defensively to these impacts, communities can begin to undertake adaptation measures that cost effectively mitigate the projected increases in risk. The NFIP could be one vehicle for helping communities begin to do this. The Community Rating System (CRS) program, which rewards communities with lower premiums when they adopt risk-reducing policies, could, for example, give credits toward premium reductions for activities that take account of future potential increases in risk. Flood maps will also need to be updated more often if the risk is changing over time, and they could begin to include projections about changes in risk levels from climate change to help communities plan.

3.6 We Take Deep Pride in Rebuilding After a Disaster

Research in cognitive psychology suggests that after a flood, homeowners are likely to overestimate risk as it has become more salient (e.g., Tversky and Kahneman 1973). If this is the case, one might expect to see withdrawal from risky areas after a major disaster. In some places this did occur after the 1993 flood, but in other areas of the St. Louis region, the opposite was observed. Instead of shrinking from hazardous locations, individuals got right back to work—rebuilding was undertaken with enthusiasm. Sometimes, but not always, the flood led individuals and businesses to adopt some mitigating activities with the rebuilding. For example, one business owner in Chesterfield Valley located all the computers on the second floor of the office after the flood, leaving the first floor for expendable items, while others decided to purchase flood insurance (Heisler 2003b).

Chesterfield again provides an example of rebuilding after a disaster. At the time of the flood, about one-third of the firms in the floodplain were renters, most of whom left the Valley, while the two-thirds who owned their property for the most part rebuilt (Manor 1994). It seems floodplain residents do not shrink from the risk: “rebuilding in the same doomed locations has become a point of pride, of dignity—just the opposite of what it should be,” (Ripley 2006).

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[9] For more details go to http://www.epa.gov/climatechange/effects/coastal/front.pdf

Thom Sehnert, owner of a popular restaurant in the Valley called Annie Gunn's, remarked: "We couldn't control the flood. That was an act of nature. But we could control how we reacted to it, and we did look at it as a definite opportunity to rebuild. We re-opened seven months after the flood, the first business back in the Valley," (Desloge 2005).

A particularly troubling type of rebuilding for the NFIP is the reconstruction of repetitive loss properties. Used here, repetitive loss properties are those with two or more losses of $1,000 or more in a 10-year rolling period that were more than 10 days apart. Repetitive loss properties comprise only about 1 percent of properties in the NFIP, but they are responsible for 25 to 30 percent of claims (Jenkins 2005). In St. Louis County, as of July 31, 2007, there were 1,156 repetitive loss properties (328 of which had four or more losses) to which over $60 million had been paid (NFIP 2007).

In 1994, some actions were taken in the National Flood Insurance Reform Act to reduce losses associated with repetitive loss properties and other rebuilding in hazardous areas. The Increased Cost of Compliance program, for example, pays up to $30,000 for repetitively or substantially damaged properties to undertake mitigation measures that will bring the structure into compliance with floodplain regulations. Also in place is the Flood Mitigation Assistance Program, which provides funding to states and communities for mitigation activities. More recently, the 2004 Flood Insurance Reform Act instituted a pilot program to reduce the number of repetitive loss properties by funding mitigation or their purchase. Under this pilot, if homeowners do not agree to mitigation or a purchase offer, their premium will increase 50 percent and then another 50 percent for each subsequent claim, until the premium subsidy is eliminated (Jenkins 2005; Bingham et al. 2006).

4. Long-Term Flood Insurance

As an alternative to standard annual insurance policies, the NFIP could consider designing long-term insurance (LTI) policies coupled with long-term mitigation loans, both tied to the property.[10] We discuss in this section how a LTI policy that protects homeowners against floods can address the six challenges outlined in Section 3. This insurance policy could be required as a condition for having a federally insured mortgage, as is the case today. Alternatively, everyone residing in an area subject to potential flooding could be required to take

[10] For more details on LTI beyond the NFIP, see Jaffee et al. 2008.

out the insurance, just as those who own a car are required to take out automobile insurance, whether or not they are financing the purchase of their car. If a property owner moved to another location, the flood insurance policy would remain with the structure.

A long-term flood insurance program would offer homeowners currently residing in flood-prone areas a fixed rate for a fixed period of time (e.g., 5, 10, or 20 years). If the homeowner moved away from the area before the end of the policy period, then the insurance policy would automatically be transferred to the new property owner at the same rate. Homeowners who were being charged subsidized rates because their homes were constructed before their community joined the NFIP would keep these rates for the length of the policy period. After the completion of one long-term contract, these properties could face actuarial rates, helping to move the NFIP to financial soundness. Rates for homeowners who constructed homes after the date their community joined the program would be actuarially based, as is the case today. These multiyear insurance policies could be coupled with long-term loans to finance mitigating activities, which, if undertaken, would reduce premiums. Here we briefly address the six challenges and how LTI and mitigation loans could help overcome them.

4.1 Many Property Owners Don't Buy Flood Insurance

Individuals in many hazard-prone areas do not have flood insurance. Consider the August 1998 flood in northern Vermont. Of the 1,549 victims of this disaster, FEMA found that 84 percent of residents in 100-year floodplains did not have insurance, 45 percent of whom were required to purchase this coverage (Tobin and Calfee 2005). As stated earlier, in St. Louis County, only about 1 percent of all properties, or 15 percent of properties in 100-year floodplains, have insurance. The 2000 U.S. Census estimates that almost 72 percent of homeowners in St. Louis County have a mortgage, suggesting that if compliance with the mandatory purchase requirement were universal, take-up rates in 100-year floodplains should be larger than 15 percent.

Given these statistics, as well as the potential savings in disaster relief, a case can be made for requiring flood coverage of all property owners in hazard-prone areas. Long-term policies would prevent property owners from cancelling their policies soon after taking out their mortgage or after they have not experienced a flood for several years. Even though today property owners are required to purchase a policy as a condition for a federally insured mortgage, banks and financial institutions often have not enforced this regulation because few of them have been fined and/or the mortgages are transferred to banks that have not focused on

either the flood hazard risk or the requirement that homeowners may have to purchase this coverage. With a long-term policy, less enforcement would be needed.

4.2 People Underestimate Flood Risk

A long-term flood insurance policy would enable the NFIP to highlight the nature of flood risk by using a time horizon that individuals can appreciate and take seriously. If the NFIP offered a 25-year policy to a homeowner residing in a 100-year floodplain, it could state that the chances of having at least one flood that could damage the property during the 25 years is greater than 1 in 5 (it is actually .22). Individuals are probably more likely to appreciate the risk when it is presented in these terms. It is highly likely that one reason homeowners do not purchase flood coverage when they are told they are residing in the 100-year floodplain is that they perceive a probability of 1 in 100 to be below their threshold level of concern. If they are presented the same likelihood data using a 25-year time horizon as a reference point, they may find a LTI policy more attractive.

4.3 We Need Better Flood Maps

Current flood maps are often woefully out-of-date. If insurance is to be used as a means of informing people about the risks they face, encouraging investment in mitigation, and providing funds to aid the recovery process in the event of losses, then it needs to adhere to the principle that premiums should reflect risk. To satisfy this principle, we need accurate flood maps that delineate flood hazard by geographic area. To support the determination of a LTI rate, flood insurance rate maps would also need to indicate areas of future development, sea level rise, and other changes in conditions that could alter flood risk over time. And, with or without LTI policies, a mechanism for regular updating of flood maps is needed.

4.4 We Have a "Love Affair" with Levees

Currently, property owners located behind levees that are certified as protecting against the 100-year flood are not required to buy flood insurance. When a levee fails, however, the damage to structures behind it can be severe. St. Louis residents are familiar with this as they witnessed the Monarch Chesterfield levee failure in 1993, which flooded the Valley like a bathtub with a story of water. Due to this residual risk, a case can be made that individuals behind levees should still be required to purchase insurance. The rate would presumably decline as the strength of the levee protecting them increased. Of course, levees need to be monitored and maintained since they may fall into disrepair, as seen in communities across the river from

St. Louis in Illinois. Long-term contracts would need to have provisions that allow changes in rates if the structural protection of a community changes. If the levees are not maintained, rates would rise. Conversely, if protection is increased, rates would fall.

4.5 Flood Risk is Increasing Over Time

It may be desirable to set flood insurance rates for LTI at a fixed price so that property owners are provided with financial stability. Of course, increasing property values would need to be reflected in a changing coverage level even if the risk itself remained stable over time. If flood risk is increasing and there is knowledge as to what trajectory the change is likely to take, this could be built into the premium structure for the long-term policy. To illustrate this point, suppose that experts knew that the expected losses to a house would increase by 1 percent per year over the next 20 years. If a premium based on risk cost $1,000 today, then it would cost $1,010 next year and $1,200 twenty years from now. The NFIP could charge a fixed annual premium to the property owner of $1,100 for each of the next 20 years.

If there were uncertainty regarding the changing risk over time, then the NFIP would have to rely on the best estimates by climate scientists, hydrologists, and engineers as to how expected flood losses are likely to change. Premiums would have to be set so that the NFIP felt they had the best estimates of future risks, knowing that there is some ambiguity surrounding these figures.

Currently, the NFIP sets premiums by looking backward, that is, by basing premiums on a historical average loss year. Private insurers, on the other hand, often set premiums by looking forward, modeling what they expect the risk to be over the life of the contract. If the NFIP moved to long-term contracts, it would need to consider being more forward-looking in its pricing. Of course, this may be useful even with one-year contracts.

4.6 We Take Deep Pride in Rebuilding After a Disaster

To encourage individuals to invest in cost-effective mitigation measures, long-term loans could be provided to the property owner. Consider the following simple example. Suppose a property owner could invest $1,500 to flood-proof his home so as to reduce water damage by $30,000 from a future flood with an annual probability of 1 in 100. The NFIP should be willing to reduce the annual premium by $300 (i.e., 1/100 × $30,000) to reflect the lower expected losses that would occur in the event of a flood. If the house was expected to last for 10 or more years, the net present value of the expected benefit of investing in this measure would exceed the upfront cost at an annual discount rate as high as 15 percent.

Today many property owners would be reluctant to incur the $1,500 expenditure, because they would only get $300 back next year and are likely to only consider the benefits over the next few years when making their decision. If they underweight the future, the expected discounted benefits would likely be less than the $1,500 upfront cost. In addition, budget constraints could discourage them from investing in the mitigation measure or the family may not be clear how long they will reside in the house and/or whether their insurer would reward them again when their policy is renewed. There may also be a failure to appreciate the economic interdependencies associated with floods, earthquakes, and other disasters. More specifically, by investing in certain mitigation measures, one would not only reduce the potential losses to one's own property, but alleviate damage to neighboring structures, or indirect costs to the community, such as interruption of business.

If a 20-year flood insurance policy were tied to the property, then the homeowner could take out a 20-year $1,500 home improvement loan at an annual interest rate of, say, 10 percent, resulting in payments of $145 per year. If the insurance premium was reduced by $300, the savings to the homeowner each year would be $155. Long-term insurance and mitigation loans would constitute a new financial product. Lenders issuing mortgages in areas at risk of flooding would have a financial incentive to provide this type of loan, since they would be better protected against a catastrophic loss to the property. The NFIP knows that its potential loss from a major disaster is reduced and individuals have lower annual payments. This arrangement would thus benefit all parties involved.

4.7 Other Benefits of Long-Term Flood Insurance

There are other benefits from the NFIP instituting long-term flood insurance policies. They would assure the spread of risk within the program since homeowners in flood-prone areas would not be permitted to cancel their policies. If flood insurance were required for all homeowners residing in hazard-prone areas, then there would be even greater risk spreading. This would provide much needed financial revenue for the program over time by having a much larger policy base than is currently available.

With respect to the hurricane risk, these policies would ensure that all individuals were protected against flood damage, reducing the litigation costs that ensued after hurricane Katrina between homeowners and their property insurers over whether damage was from wind or water. There would still be a question as to whether the government would be paying for some of the loss because it was caused by water or whether private insurers would be responsible because it was wind-related damage, but homeowners would be protected.

5. Conclusion

Flood damages are likely to continue to increase as flood risk is exacerbated by climate change and as we keep building in floodplains. With the National Flood Insurance Program up for renewal this spring, it is an opportune time to reassess the management of flood risk in the United States and how it can be improved. Hurricane Katrina spurred such discussion vis-à-vis hurricane and coastal flood risk and this paper has sought to complement these discussions with insights from the analysis of riverine flood risk in St. Louis, Missouri.

Open research questions still remain. More empirical research on why take-up rates are dismally low for flood insurance would be useful for guiding reform of the NFIP. Such studies should also investigate the differences between inland and coastal areas regarding residents' risk information, perceptions of flood risk, and perceptions of the NFIP. Improved understanding of what type of risk communication and what mode of information transmission are most effective in spurring mitigation would also help guide policy. Finally, discussion is needed on how the NFIP can more effectively address changes in flood risk over time, such as from development or structural changes to rivers. Further, the NFIP could be used to help communities begin to adapt to projected changes in flood risk from climate change. How that can be accomplished requires careful consideration.

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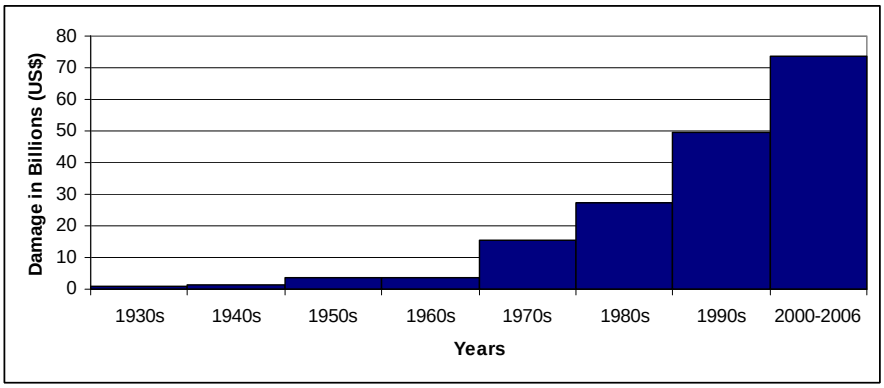
Figure 1. Total Direct Damages from Flooding in the United States by Decade



Data from the National Weather Service and http://www.flooddamagedata.org.

Figure 2. Rivers and Floodplains of St. Louis City and County

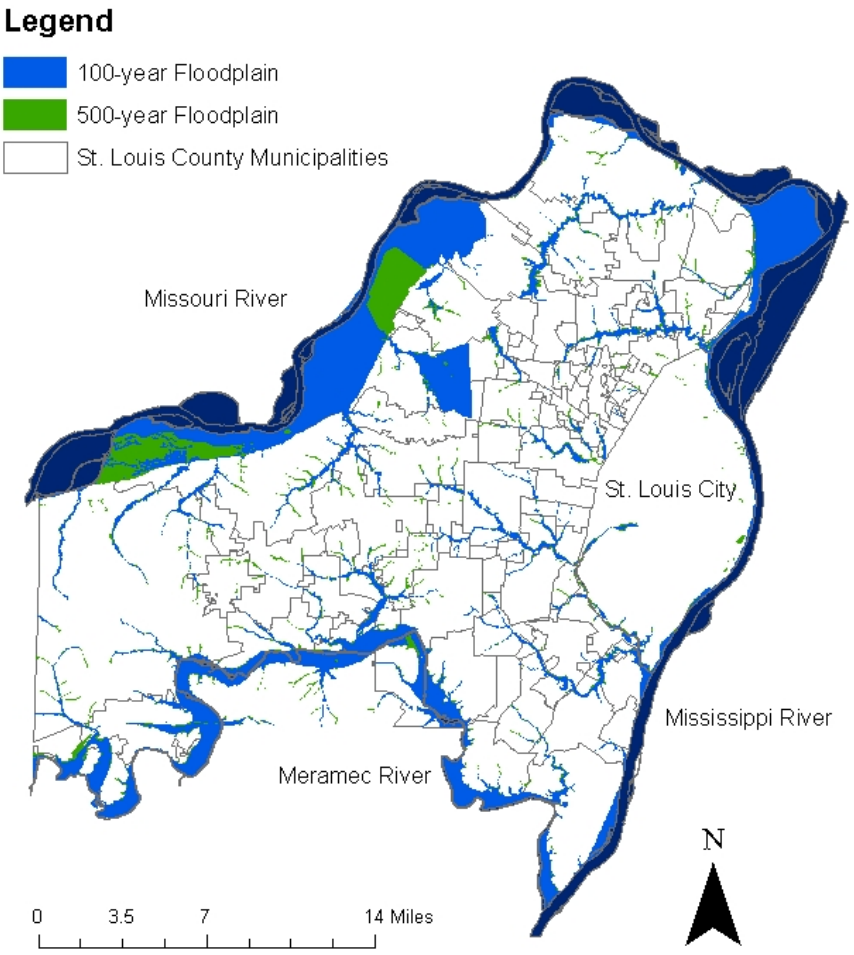
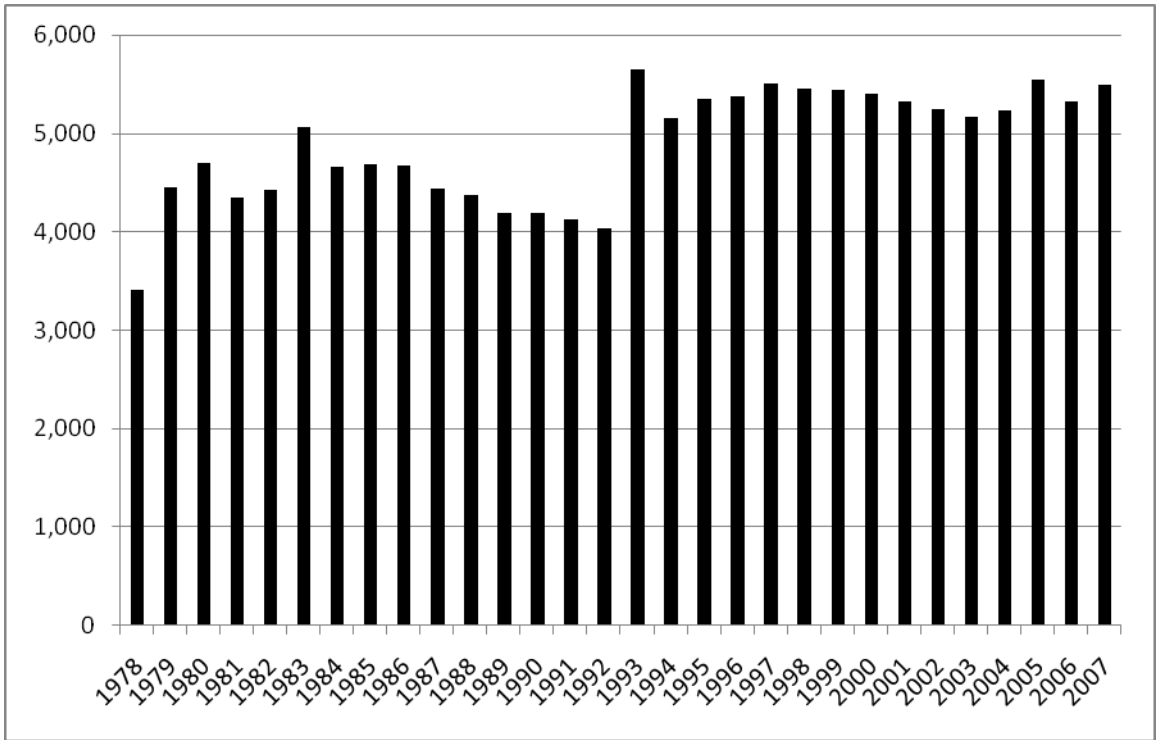


Figure 3. Policies-in-Force in St. Louis County, Missouri, 1978–2007



Data from the Federal Emergency Management Agency.

Figure 4. NFIP Claims (in US$) from St. Louis County for 1993 and 1994

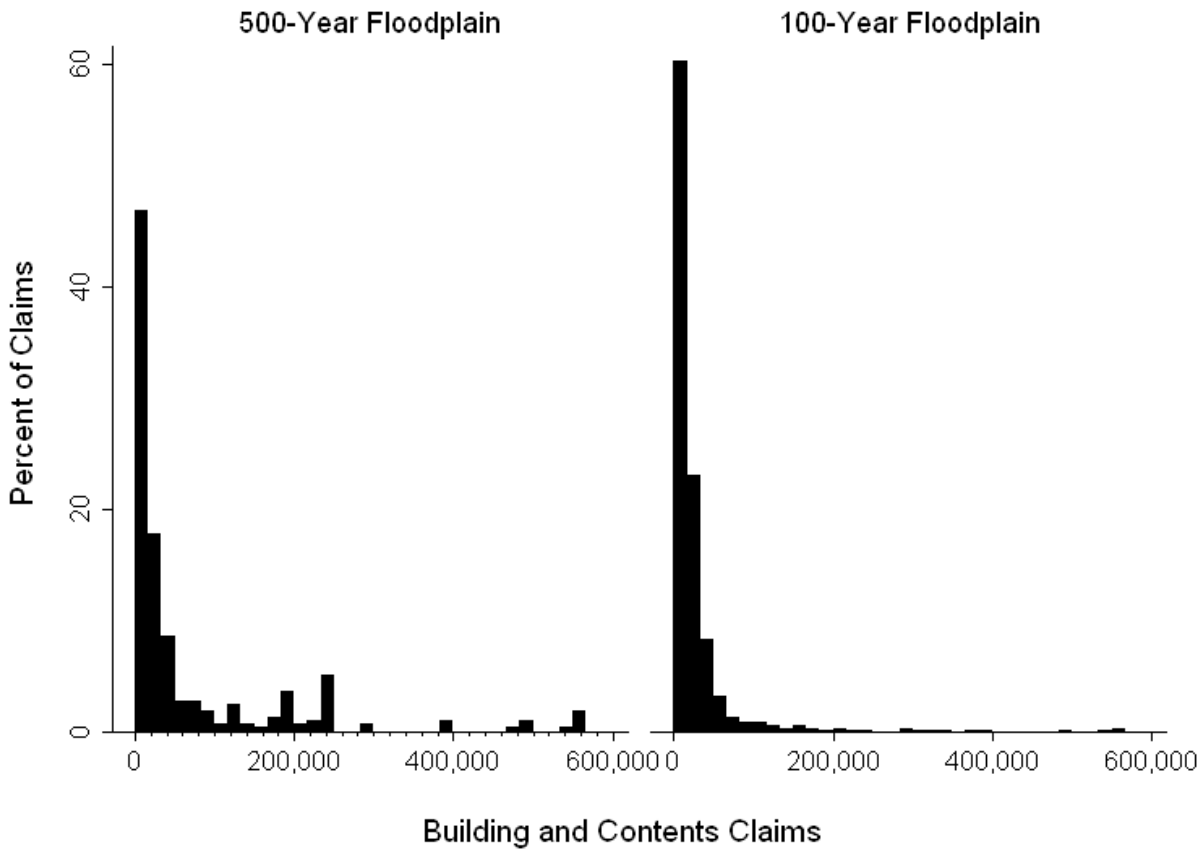


Figure 5a. Maximum Height of the Mississippi River at St. Louis Plotted by Year, 1900–2007

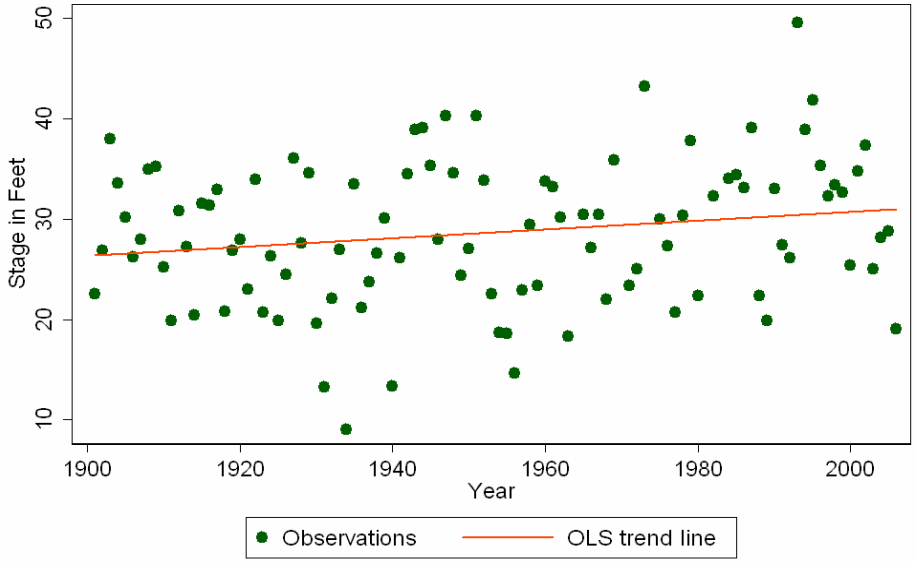
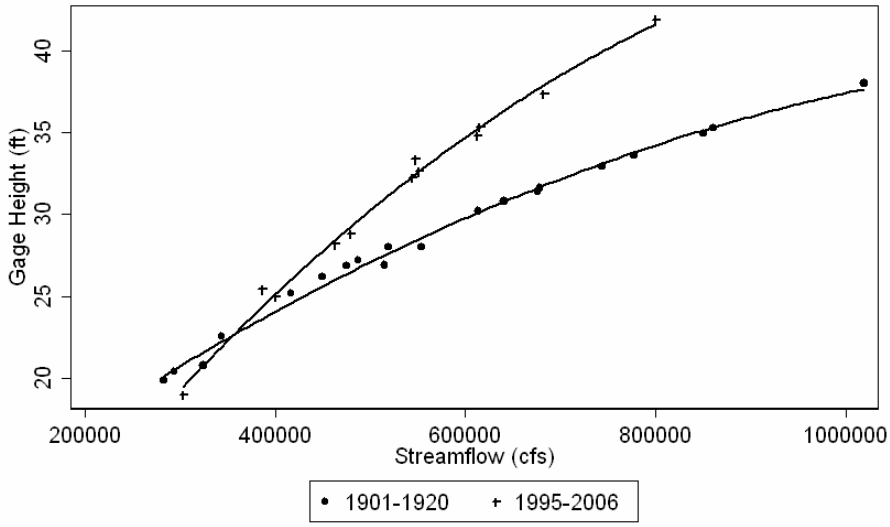


Figure 5b. Maximum Height of the Mississippi River at St. Louis by Streamflow Plotted for 1901-1920 and 1995-2006



Data from U.S. Geological Service.