River Ecology and Flood Hazard Mitigation

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Abstract: Flooding remains the most common and one of the most costly categories of natural hazards in the United States. Historically, the United States has relied on structural mitigation, insurance, and disaster relief to mitigate the harm done by floods. However, experience has shown that structural mitigation and related policies can fail to protect lives and property while also contributing to the degradation of the riverine environment. We review flood hazard mitigation policy, describe some of the environmental damage associated with current policies, and review current policy proposals to outline ways to mitigate the flood hazard without promoting catastrophic losses and environmental damage.

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Introduction

Flood losses in the United States continue to mount, despite three centuries of efforts to control rivers and protect life and property (Haeuber and Michener 1998; Platt 1999). National Oceanic and Atmospheric Administration national flood loss data for the first 20 years and last 20 years of the twentieth century show average U.S. annual riverine-related flood damage (1997 constant dollars) rising from $1.76 billion to $4.4 billion (U.S. National 2000). The data show substantially increasing damages associated with lower frequency catastrophic-level flooding. In some instances the capacity of flood control systems is exceeded and human encroachment on floodplains results in especially high damage levels. Indeed, floods are among the costliest natural hazards in the United States (Conrad et al. 1998; Kolber 1999). Fig. 1 shows the increasing annual damage toll associated with flooding.

In this paper, we connect two very important issues in natural resource management—flood hazard mitigation, and the maintenance and restoration of riverine ecosystems. We begin by discussing the most commonly used flood mitigation policies. We show that, despite the availability of effective and environmentally sound hazard mitigation tools, the United States, like most developed countries, shows a marked disposition to control nature rather than work with it (Nash 1982; McPhee 1989), as reflected in structural mitigation measures that require little or no change in individual or collective human behavior. Our ability to manipulate nature to protect lives and property from catastrophic flooding is limited. Continued attempts to do so, particularly in areas where other, less costly alternatives exist, often result in significant environmental degradation (Gillis 1973, p. 677).

We then turn to a brief discussion of the ecological consequences of these dominant policies. Working with nature is a fundamental feature of sound hazard mitigation, particularly in floods. Pioneering research on the relationship between floods and human behavior was conducted by geographer Gilbert White, who has been arguing for more than 50 years that greater attention should be paid to working with nature instead of against it (White 1936, 1945, 1975a,b, 1977; White et al. 1958; Myers and White 1993). Connecting thinking and action about flood hazards to broader environmental concerns would be an important part of efforts approaching environmentally and socially sustainable natural hazard mitigation (Mileti 1999).

In discussing these policies we show that, increasingly, citizens, scientists, and policymakers recognize that reduction of flood damage must involve social and economic trade-offs that go beyond the more immediate issues of mitigation. We show that significant changes in attitudes and practices relating to rivers and floods are necessary to promote sound riverine ecology while protecting people and property from floods. Policy changes, based on sound science, are needed at the national, state, and local levels. It is important for citizens and professionals concerned with the mounting costs of traditional mitigation techniques, and their sometimes catastrophic failures, to understand the need for policies that protect riverine ecosystems and their benefits to natural and human systems while mitigating flood damage.

We conclude by noting that the recommendations we make are not novel, but are based on years of scientific and practical experience. But because of the nature of the flood problem and the most fruitful mitigation techniques, we argue that an active federal role in policy-making, coupled with extensive local coopera tion in implementation, is required for successful flood mitigation policy that protects the environment, people, and property.

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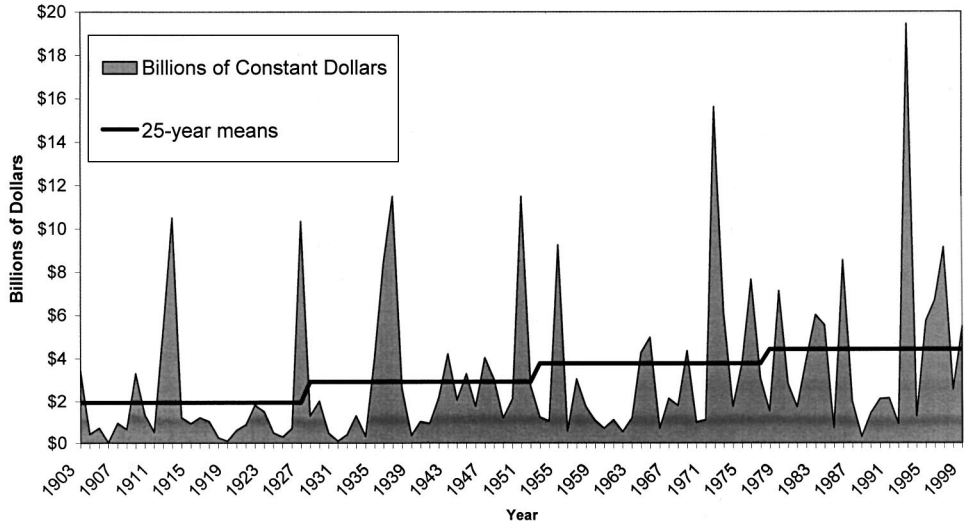

Fig. 1. Historic flood losses, 1903–1999

Dominant Flood Mitigation Policies

For years, and most clearly since the 1927 Mississippi River floods, structural mitigation techniques—dams, levees, floodwalls, diversion channels, and the like—have dominated flood policy approaches in the United States. There are many reasons for this dominance, and each reason relates to the preferences of particular interests. First, structural mitigation projects sometimes fulfill multiple purposes that satisfy the needs of multiple interests. A dam, for example, can be operated to address flood control, navigation, irrigation, power, recreational, and fish and wildlife interests. Historically, environmental interests were the last to be added to the equation. Second, federal flood control projects are promoted by the Army Corps of Engineers in a symbiotic relationship with local political and economic interests. The Corps has considerable staff expertise and experience in building structures along rivers, while such projects are locally popular because they create a sense of security from floods while providing local workers and business with jobs, construction and supply contracts, and the like. Such projects allow members of Congress to claim that they have ''brought home the bacon'' to their local districts. Finally, structural mitigation *works* when we define ''works'' as protecting a community from routine floods. A flood of record can breach flood control structures, and flood control structures built to protect one community may result in a greater flood hazard in other communities across the river or downstream from the protected community.

In recognition of the fact that flood control structures by themselves cannot alleviate all damage from flooding, Congress established the National Flood Insurance Program (NFIP) in 1968. This program was intended to reduce the economic damage done to individuals by flooding by compensating victims and by encouraging communities to adopt mitigation techniques through building and land use practices, such as elevating structures or not building in floodplains. The goal was, in part, to redirect people and property from future flood damage, thereby making flood damage less costly and disruptive to communities.

The NFIP has been at best a mixed success. Numerous insured properties have been repetitively flooded, and insurance claims have repeatedly been paid to their owners, when the fiscally and environmentally sound solution would be to remove the structure from the flood prone area (Conrad et al. 1998). The NFIP is further saddled by not being able to charge actuarially sound rates for approximately 40% of the properties insured, although some efforts are being made to change the program to reduce repetitive losses and to eliminate rate subsidies.

Finally, one must consider disaster relief programs in the context of mitigation, because disaster relief discourages effective mitigation by subsidizing risky behavior, in much the same way that some insurance programs create a ''moral hazard.'' A moral hazard refers to the existence of insurance against a risk that may cause people to be less diligent about mitigating risk, relying instead on insurance to compensate for any disaster. Postdisaster relief is currently so generous and carries so few conditions that some local communities substitute often-ineffective structural flood control and disaster relief for careful land use and environmental management that would, in the long run, actually save money and other resources at all levels.

Ecological Consequences of Dominant Mitigation Policies

An extensive body of research documents the environmental costs associated with dams and other impoundments, regardless of whether such structures are used for power generation, irrigation, recreation, or flood control [a review of the ecological impacts of impoundments and reservoirs is provided by Baxter (1977), and encompasses many of the issues raised in this section]. This damage includes, but is not limited to, the decline of fisheries and a wide variety of aquatic species such as Pacific salmon (Baxter 1977; Czech et al. 2000; Pelley 2000); changes in patterns of sediment transfer (Baxter 1977, p. 271); changes to the river flow regime that injure its biota, particularly replacement of natural flow regimes with extreme, artificial highs and lows (Cole and Landres 1996, p. 185; Poff et al. 1997); reduction in natural flooding during periods where natural floods would be expected; and static flow regimes that fail to take into account the natural history of flora and fauna along the river. As Whiting (1998) notes, healthy streams require a variety of flows at different times and for different intervals. Economic development, and its attendant changes to land use, also can alter riverine flow regimes; when it does, it has often been accompanied by enormous adverse impacts on associated aquatic ecosystems and fish and wildlife habitat (Sparks 1995).

Scientists report in recent years that freshwater ecosystems are by far the most imperiled, due particularly to non-point-source pollution, newly introduced species, and physical alteration of natural water systems, especially by dams. In 1998, the World Wildlife Fund's *Conservation Assessment of Freshwater Ecoregions of North America* found that ''dams represent one of the most serious threats to freshwater biodiversity, as they alter hydrologic integrity and water quality, fragment habitat, and cause additional habitat loss in the form of up- and downstream changes in sediment and other parameters'' (Abell et al. 1999). The Nature Conservancy notes that in the United States today, largely due to major alterations of river flow regimes, 67% of freshwater mussels are vulnerable to extinction or are extinct, 37% of freshwater fish fauna—303 fish species—are at risk of extinction, and 51% of crayfishes and 40% of amphibians are at risk (Master et al. 1998, p. 6). Ironically, as the ecological damage caused by main stream dams has come to light and produced some impetus for policy change, the nation is embarking on a second wave of dam construction—in this case on small tributary streams to create impoundments to treat urban runoff and improve water quality. The consequences for stream ecology are equally grim, since research shows that storm water ponds create thermal pollution and other adverse environmental effects. Galli (1990) found that impervious surfaces were the primary contributor to thermal pollution of headwater streams, but that lack of riparian cover and ponds also contributed.

In sum, the adverse environmental impacts of various structures have become increasingly and alarmingly apparent. Dams and artificial channel improvements restrict the nation's largest and most important rivers (Benke 1990), and are now threatening thousands of kilometers of smaller tributary streams in urban regions throughout the country. Hundreds of streams are restricted by dams or channelization, are often cut off from their floodplains by levees, or are altered for navigation purposes. Biologists and physical scientists realize that by restoring hydrology and geomorphology to more natural conditions, damaged ecosystems can be significantly revived. Methods to restore natural systems include modifying dam operations and improving water management, reopening water access to natural floodplains, restoring riparian vegetation and habitat, using infiltration and natural buffers to treat storm water, and reestablishing natural dunes along coastlines and barrier islands.

The premise of this discussion—that restoring more natural riverine and stream flow regimes will restore natural processes and, thus, native species—is based on sound ecological and evolutionary principles (Reice 2001). Organisms adapt to their environments, and organisms that live in environments with flood pulsing have adaptations to survive or even capitalize on fluctuations in environmental conditions (Junk et al. 1989). The greater the departure from the natural regime, the more likely it is that some native species may be replaced by invasive, nonnative species that thrive in the altered regime. Thus, where the natural regime can be approximated, the recovery of native species and functions will be more likely.

Potential Policy Approaches and Their Ecological Impacts

While we recognize that structural flood control remains essential in certain areas to protect property and lives, we believe that far more emphasis must be given to developing and implementing solutions that reduce flood hazards while minimizing ecological degradation. To do so, however, requires changing cultural predispositions and acquiring public and political support for policy changes needed to break a cycle of financial losses and environmental degradation. We believe that now, in a period when all manner of natural hazard and ecological policies are being reviewed and reconsidered, is a good time to show that improved flood mitigation will provide ecological as well as hazard mitigation.

Changes in Public Perceptions of Floods

Most information about floods comes from the mass media, which continue to focus on the most obvious social and human costs of flooding. Modern communications allow the rapid transmission of dramatic, often wrenching news about flood victims to millions of people, in what Platt (1999) calls the ''CNN syndrome'' (Fischer 1989). Clearly, news organizations will select the most dramatic pictures of any natural disaster, and these images reinforce beliefs that floods are a problem that must be solved (Smith 1992). So many people have been harmed by floods in recent years, or are constantly subjected to flood hazards, that the negative aspects of floods continue to dominate public thinking. As a result, efforts to control floods—rather than alter human actions—have dominated efforts to deal with the hazard.

It will be difficult to overcome the media's predisposition toward coverage of natural disasters as simply ''acts of God.'' Rather, human decisions, made before and after disasters, play a critical role (Steinberg 2000). It is worthwhile for experts, in their dealings with the media, to remind reporters, readers, and viewers that flooding is a natural phenomenon—with positive consequences for the riverine ecosystem—to which humans must adapt and from which humans can, in the long run, profit. Adaptation of nature to humans, as we have seen, is likely to create negative ecological outcomes without mitigating catastrophic flooding.

Flood Control

Structures sometimes enhance the environment (beneficial use of dredged material is an example), but far more often they significantly degrade the environment by severely altering the natural hydrology of the river. The Army Corps of Engineers notes that its flood hazard mitigation efforts prevent billions of dollars in damage—$709 billion in constant dollars from 1928 to 2000 (U.S. Army Corps of Engineers 2001). While engineered flood control structures have clearly prevented damage, particularly in densely populated urban areas such as New Orleans and St. Louis, these and similar estimates of the value of property protected by structural mitigation often fail to account for the extent to which flood control measures induce greater development in areas nominally protected by structures (White 1945, 1958; Burby et al. 1985; Wright 1996; Stein et al. 2000).

Aside from flood damage, increased development in the floodplains has negative environmental effects, such as water pollution from storm runoff, greater urban flooding from impermeable surfaces, increased damage from historic floods that overtop levees and dams, and demand for even more expensive and often ecologically damaging structural mitigation measures as development cost and intensity increase. Thus, a cycle of structural mitigation, development, and more demand for structural mitigation begins, with constantly escalating economic and environmental costs. This cycle is evident in a range of places and scales, from a small rural levee district to large federal projects in developed areas.

When historic floods top the levees, or the levees fail, more property is exposed to damage than would have been exposed had the levee never been built (Larson 1994). This is likely due in part to what experts in hazard mitigation policy describe as the false sense of security that accompanies engineered solutions to flood control (Williams 1998), which often *encourages* development protected by flood control works (Faber 1993, p. 3), since property owners come to believe that the area has been somehow rendered completely safe from flooding. As Scott Faber noted when he was with American Rivers, in the aftermath of the Midwest floods of 1993

> The Mississippi has sent a powerful message: Shortsighted structural solutions coupled with unwise land management practices have put people and property at risk. Instead of allowing the river to fan out and take advantage of the natural flood control function of floodplains, the United States has spent billions of dollars to force the river into ever tighter channels, which raises flood crests and creates a false sense of security that has encouraged floodplain development (Faber 1993, p. 3).

Claims of the economic value of engineered solutions also fail to include the environmental costs of altering the flow regime or the riparian ecosystem. For example, it will cost at least $8 billion to restore flows in the Everglades to a more natural condition (Boucher 1995; Brown 2001; ''Putting'' 2001); this figure does not account for the value of the ecological services provided by the Everglades, such as floodwater retention. To ensure that environmental issues are properly accounted for when structural mitigation is contemplated, and to promote balanced water resources planning and management, the federal principles and guidelines (U.S. Water Resources Council 1983) should be amended to place ecological values on the same level as economic values to promote balanced water resources planning and management. A federal interagency panel of floodplain experts and a National Research Council panel have each made similar recommendations for updating these critical documents (Interagency Floodplain Management Review Committee 1994; National Research Council 1999). Executive Order 11988 (Floodplain Management) of 1977 was issued to discourage floodplain development, reduce hazards and risk associated with floods, and restore and preserve natural floodplain values. Because no agency is responsible for implementing this executive order, it has not been aggressively or effectively enforced and it fails to discourage projects that proceed regardless of the real economic benefits and the lack of risk reduction or even the creation of greater risk.

This is not to say that all structural flood mitigation should be abandoned. Clearly, as a matter of political and economic reality, structural measures will remain in place in and near densely developed urban areas. However, the construction or upgrading of facilities in rural areas must take into account both the extent to which more land development is encouraged, and the upstream and downstream environmental costs of the structures. When flood control structures are built, they sometimes raise the level of the river in the flood area by constricting, to some extent, the waterway and the natural floodplain. This shortens the flood time but often raises the flood pulse downstream and increases the velocity of the water. Tributaries that are channelized or have extensive levees (or that experience dam failure) can send large flood pulses into the main stem of the river system, which also results in greater downstream flooding. While smaller damaging floods have been averted by flood control structures, it is important to remember that, despite all of these efforts, the dollar amount of flood damage, resulting primarily from major catastrophic floods, continues to grow, as indicated in Fig. 1 (Conrad et al. 1998).

In response to the growing awareness of the limitations of traditional structural flood control approaches, in the 1999 Water Resources Development Act, Congress adopted the ''Challenge 21'' program, giving the Army Corps of Engineers substantial new authority to develop nonstructural ''flood mitigation and riverine restoration projects.'' The program suspends the requirement that such projects meet standard benefit-cost criteria. The legislation also removed other impediments to the Corps' involvement in nonstructural projects. While Congress has shown a considerable amount of interest in authorizing projects, appropriations for planning and construction of such projects have thus far not materialized.

Given these features of flooding and the policy responses to floods, we recommend that federal agencies address flood hazards by using one or a combination of the following techniques, listed in descending order of desirability:

1. Avoid the risk.
2. Minimize impacts of risk.
3. Mitigate risks.
4. Indemnify or insure against loss; compensate.

Risk avoidance is at the heart of Executive Order 11988's mandate; if this executive order were more effectively implemented, our recommendation would be implicitly adopted, with risk avoidance becoming the preferred tool. Currently, however, federal agencies seek primarily to mitigate and indemnify, not to avoid risks whenever possible.

Relief

The emphasis on engineering solutions to prevent catastrophes, combined with the mounting costs of flood damage, has led to policy changes at the Federal Emergency Management Agency (FEMA) to encourage improved hazard mitigation and to discourage building near flood areas. These initiatives have included FEMA's Project Impact, which encourages local governments to become more active in mitigation planning and implementation, and the Hazard Mitigation Grant Program (HMGP), created by Section 404 of the Stafford Disaster Relief and Emergency Assistance Act. The HMGP has been particularly useful as a source of funds for buying out property owners who live in hazardous floodplains. While the HMGP is not promoted as an environmental program, and its environmental benefits are often subordinated to other claimed benefits, such as savings in disaster relief, the HMGP can be used to obtain ecological benefits, as the National Wildlife Federation has illustrated in its ''Higher ground'' report (Conrad et al. 1998). And while Project Impact may not be continued in the Bush administration, its legacy continues at the local levels, where efforts to educate citizens, community leaders, and elected officials have raised awareness of floods and other hazards.

FEMA can contribute to these efforts by incorporating environmental goals into its disaster relief, recovery, and mitigation work. Such efforts would be consistent with FEMA's statement of its own environmental responsibilities (at its Web site, http://www.fema.gov/mit/ep/laws.htm), and the *Code of Federal Regulations* (44 CFR 10.4), which states that ''FEMA shall act with care to assure that, in carrying out its responsibilities, including disaster planning, response and recovery and hazard mitigation and flood insurance, it does so in a manner consistent with national environmental policies.'' We argue that FEMA can go

beyond mere ''consistency with national environmental policies'' by making environmental protection and ecosystem improvement a key part of its disaster mitigation mission, rather than simply a matter of regulatory or statutory compliance. Integrating hazards mitigation goals with natural resource issues will promote closer ties between the environmental agencies (Fish and Wildlife or Bureau of Land Management, for example).

Flood Insurance

The FEMA-managed NFIP dominates current nonstructural flood mitigation measures. Congress first authorized the NFIP in 1968 to provide otherwise unavailable flood insurance to floodplain occupants. Insurance would only be available in communities that adopted at least minimum land use controls and building codes to guide new development away from special flood hazard areas—defined as areas inundated by the 1% annual chance flood, also known as the 100-year flood. There are 4.2 million policies in force, which are significantly subsidized by taxpayers. If premiums for property that existed before the original establishment of the flood insurance rate maps (generally 1974 or later) were based on actuarial rates, flood insurance premiums would average between $1,100 and $1,200 annually (Conrad et al. 1998). Moreover, unlike private insurance companies that are declared insolvent when outlays exceed income, FEMA, which manages the NFIP, simply exercises its authority to borrow from the federal treasury to cover excessive outlays. This borrowing, which is due in part to the decision by Congress to subsidize rates for a significant proportion of policies, has led to considerable deficit spending by the NFIP; from 1986 to 1997, the NFIP ran a total deficit of $1.1 billion (Platt 1999, p. 31). In the mid-1980s, Congress waived the requirement to repay $1.2 billion in funds lent to the NFIP by the federal treasury because premiums were generating insufficient sums to keep the program solvent.

In addition, the extent of repetitive loss properties in the NFIP shows that some people are more willing simply to collect insurance payments than move out of their flood prone properties. Repetitive loss structures—those that have received two or more flood insurance claims of $1,000 or more within any 10-year period—have received 40% of NFIP payments, totaling $3.8 billion since 1978, although they constitute only 2% of all insured properties. Of these payments, approximately half were paid to properties flooded three or more times. While most private insurance carriers would raise their premiums or drop the property owner's insurance coverage, the NFIP is politically prevented from doing so. In this way, flood insurance begins to resemble much of the federal disaster relief policy—an entitlement program through which qualified disaster victims may expect to be compensated regardless of their efforts, or lack thereof, to mitigate the risk (Platt 1999; Association of State Floodplain Managers 2000).

In the flooding case, without insurance or any other protective measures provided by the government, property owners would be required to bear 100% of the risk of living in a floodplain, and they likely would take steps on their own to reduce the chances that their property would be damaged by flooding. The most affordable steps—retreat from the floodplain and, in some cases, retreat from the property in toto—would also yield important ecological benefits, because, with less property to ''protect,'' rivers could return to their regular flooding regime. When insurance is provided, however, property owners are less willing to retreat or are less willing to take steps to protect themselves, or actually become more likely to expose themselves to flood losses. Because of the phenomenon of moral hazard, insurance can lead to greater exposure to loss than would have occurred had it never been made available (Kunreuther and Roth 1998). Moral hazard applies to those property owners who have the financial wherewithal to choose whether or not to live in a hazardous area. It also applies to developers and policymakers who choose to allow low-income residential development in hazardous areas, in the belief that such areas are the only land available for affordable housing, and that, in any case, the residents of such housing will themselves be able to take advantage of flood insurance.

Compounding the moral hazard problem is another insurance term called ''adverse selection.'' Adverse selection describes a situation where the purchasers of insurance are only those who are exposed to the greatest risk. Private insurers use a number of techniques to avoid adverse selection and spread the risk more broadly. Perhaps the most obvious tools are to refuse to insure the risk or to charge different premiums based on differences in risk, much as insurers do for automobile, life, and fire insurance. Current law and practice prevent the NFIP from refusing to insure properties located in communities participating in the program, and from charging rates based on the actual loss experience of individual properties. The result is that owners of properties that have been repeatedly flooded cannot be compelled to pay higher rates for insurance based on their risk profile. Nor can the NFIP refuse to insure a property that has been flooded numerous times.

The economic rationale for insurance is that it will internalize the cost of using building sites in floodplains, thereby favoring development in flood-free sites. But if property owners can easily evade these costs, that economic discipline is missing. Thus, only the most seriously flood prone occupants purchase insurance; risk is therefore inadequately distributed because of adverse selection, and the long-term need for taxpayer subsidies is created. The adverse selection problem is why private insurance companies refused to write flood insurance in the first place. The NFIP community land use regulations—and, in particular, the requirement to elevate new construction—can mitigate some flood damage. However, as noted before, the requirement to carry flood insurance allows, and may even encourage, development in flood prone areas.

Another problem with the NFIP—with significant ramifications for floodplain function—is the degree to which the program allows developers to fill the floodplain (including wetlands) to elevate building sites. The NFIP requires, for instance, that buildings be elevated and that the ground floor of vulnerable structures not be used for habitation. While such fill can result in enormous environmental damage, FEMA's regulations allow the practice so long as the development will not obstruct the floodwaters and result in a greater than 30.5 cm (12 in.) rise in the 100-year flood on adjacent properties. A number of states have adopted a more restrictive ''zero-rise'' floodway standard that bars most fill in the floodplain, unless the developer buys easements to compensate for the increased flooding on adjacent lands.

An additional and critical problem is that a large number of NFIP rate maps, which identify the location and, in many instances, the elevation of the base (1% annual chance) floods, are seriously out of date. They do not reflect upstream watershed development that can significantly affect floodplain hydrology and the longer period of hydrologic record now available. FEMA reports that 33% of its rate maps are more than 15 years old, and another 30% are 10–15 years old. FEMA is currently asking Congress for funds to begin what may ultimately be an $850 million, seven-year national effort to update floodplain maps. In the wake of devastating Hurricanes Fran and Floyd with flood levels far

higher than old maps would have predicted, FEMA and the state of North Carolina recently decided to embark on an aggressive program to remap the entire state's floodplains on an expedited basis (Reckhow 2001).

Finally, the NFIP's mandatory flood insurance purchase requirement and community land use and building elevation requirements apply only to the ''regulated'' 100-year floodplain—that is, only the floodplain identified in FEMA flood maps with a 2% per annum flood probability. The NFIP requirements do not apply to other areas, outside the regulated floodplain, which may, due to changes in land use along a river, become subject to the same flood risk as the regulated floodplain. Many communities seek a minimum ''100-year'' level of structural flood protection to evade these restrictions, without providing for flood hazard mitigation for the remaining (or ''residual risk'') areas of floodplains. Thus, in dam or levee ''protected'' floodplain areas, even more building is encouraged with neither insurance nor building elevation required, even as the possibility of a catastrophic flood increases.

To summarize, many features of the NFIP have the unintended effect of inducing land use and construction behavior that encourages ecologically unsound practices in the floodplain.

Improvements to NFIP

Recent improvements to the NFIP are beginning to show some promise. First, the basic community land use and building code requirements, when properly enforced, can significantly reduce the level of risk and damage to lives and property to new development in the floodplain. If communities choose to zone floodplain areas for low-density residential uses or to acquire portions of the floodplain for parks, greenways, and open space, there is also considerable potential for ecosystem restoration (Conrad et al. 1998). Communities may also choose to regulate floodplain areas for water quality, as riparian buffers can help filter runoff (Lowrance et al. 2000). Choices on whether and to what extent to restrict development in a community are left to the local government, but current programs provide important incentives for improved flood mitigation policies. FEMA's NFIP Community Rating System (CRS)—a *voluntary* program for communities that implement measures such as open space zoning and removal of high-risk buildings from floodplains—establishes the incentive of reduced insurance cost when communities implement mitigation measures beyond the minimum participation requirements. The incentive has had some effect, but less than 10% of the communities participating in the NFIP have qualified for insurance rate reductions under the CRS by taking extra steps to avoid flood losses.

Second, beginning in 1994, the NFIP began to focus more seriously on the use of nonstructural hazard mitigation—especially the use of voluntary buyouts to help residents and businesses relocate out of floodplains and other hazardous areas (Godschalk et al. 1998). FEMA's Flood Mitigation Assistance Program, now funded at $20 million annually and complemented by much larger Stafford Act's HMGP funding, has created even greater potential for the restoration of floodplain ecosystems. This program functions in previously developed areas, primarily through buyouts and permanent dedication of land for open space uses. Since the 1993 Midwest Flood, FEMA has spent over $1 billion to buy out and remove over 29,000 floodplain properties, mostly after flood disasters (Federal Emergency Management Agency 2001).

One might argue that while floods are high consequence events, they are low probability events in any one location, which may reduce the cost-effectiveness of some potential mitigation efforts. This argument, while true of many hazards such as earthquakes and hurricanes, may not hold as true for flooding, which can be chronic as well as catastrophic. As noted earlier, the National Wildlife Federation's ''Higher ground'' report found that between 1978 and 1995 2% of properties in the NFIP made claims of more than $1,000 more than once, accounting for over 40% of all claims, and that almost 10% of single family residential claimants were paid—over this 18 year period—more than the value of their insured property. The highest payout was nearly *seven times* the value of the property. This repetitive loss rate further reflects the adverse selection problem. The National Wildlife Federation and others argue that a policy of buyouts from the floodplain along with protecting floodplain functions and purchasing floodplain land and easements to restrict future unwise development would be the most effective tool for mitigating losses. At the same time, such a policy of discouraging floodplain development will yield ecological benefits (Conrad et al. 1998).

Subsidies

Subsidies can work at cross-purposes with wise natural resource management and hazard mitigation by creating perverse incentives for individuals and communities. Because they act on signals that may create incentives to take risks, the parties best able to reduce their exposure to risk, such as homeowners, do not have the incentive to do so. In particular, public assistance in the wake of disasters—particularly to local governments—is generous and comes with relatively few restrictions, so some local communities don't engage in more effective mitigation activities. The result is that less effective structural flood control and other infrastructure projects are promoted over careful land use and environmental management. Disaster relief should therefore be structured to provide incentives to communities to take extra efforts to reduce risks, and to require that all communities participate in the NFIP as a condition for receiving disaster relief. Local governments should also be required to assume a larger share of the costs of structural mitigation projects; the current 65% federal cost share leads communities to continue to believe that flooding is fundamentally a federal problem with little state or local responsibility. The goal of increasing local cost sharing is to encourage a move from ''flood control'' toward a more encompassing notion of ''floodplain management'' and beyond, to watershed management or water resources management. After all, communities that must pay for a greater share of the costs of constructed flood control measures, such as levees, may become motivated to consider lower cost alternatives that promote mitigation and environmental quality.

Clearly, policy change will be difficult to achieve, but there is considerable reason to believe that a window of opportunity is opening that will help proponents of more ecologically and economically sound flood hazard mitigation achieve their goals. Clearly there is movement in Congress and the Executive Branch as well as in numerous states and literally hundreds of communities toward a substantial increase in emphasis on hazard mitigation and especially on removing or relocating many of the most highly vulnerable buildings from floodplains—a stark change from past experience (Conrad et al. 1998). A fundamental shift is needed to place more responsibility on those closest to the floodplain—first and foremost on floodplain residents and commercial interests; secondly, on local and state governments that exercise land use authority; and, finally, on the federal government.

The NFIP can be reformed to create incentives for people to change their behavior, thereby minimizing flood damage and helping to maintain the ecological functions of rivers and streams, through various means, as follows:

- All flood insurance premiums should be based on actuarial rates based on risk potential. Such rate setting will require that subsidies to older properties be eliminated and that federal flood maps be updated. Map revisions will cost between $750 million and over $1 billion, but this cost is small compared to the accumulated historic shortfalls in the flood insurance program. The result would be to reduce the attractiveness of residing within the high-risk floodplain areas, thereby reinforcing the signal sent by actuarial rates.
- Provide increased funding for the mitigation of repetitive loss structures and eliminate subsidies for those properties where legitimate mitigation offers are refused.
- Substantially reduce incentives for filling of floodplain areas, especially through the adoption of a no-rise floodway. This would mandate that any structure built in the floodplain would not result in higher floodwaters than have been historically experienced along the floodway or floodplain.
- Increase the flow of information concerning floodplain management and nonstructural solutions to localities and states, including a vastly increased effort to update old floodplain maps and complete the mapping of unmapped floodplains. Project Impact was a start in this regard, but there is much more to be done, particularly now that the Bush administration has chosen not to continue Project Impact.

Land Use

The most promising way to yield ecological benefits while mitigating damage to people and property is to discourage inappropriate land use in or near floodplains. Such inappropriate, high-risk uses include intensive agriculture and residential development. Intensive commercial developments are particularly worrisome because they are often accompanied by large parking lots and other impermeable surfaces that exacerbate flooding caused by runoff.

Planning and zoning have been important tools for local governments to improve local quality of life and safety since the 1920s (May and Deyle 1998). Improved land use policy is often cited as a particularly effective form of flood hazard mitigation (Sheaffer 1976; Alesch and Petak 1986; Burby et al. 1990, 1999; Burby and Dalton 1993; Berke and French 1994; Dalton and Burby 1994; Berke et al. 1996; Burby 1998). Examples of such improved land use practices that could mitigate flood damage and improve natural systems include preserving wetlands, creating wildlife habitat, setting aside recreational areas and open space, or, in some cases, promoting low intensity agriculture. Any lower density development would result in exposing fewer lives and less property to the risk of loss, but land use policy that recognizes and preserves, to the extent possible, the existing ecological function of a river system will pay substantial benefits in damage mitigation and improved ecological function.

Many political and perceptual obstacles must be overcome before land use policies are used more widely. Burby and French (1981) studied 1,200 governments participating in the National Flood Insurance Program and identified a ''land use management paradox.'' That is, improved land use practices work by *preventing* flood problems from developing. Until there is a damaging flood, however, most local governments give scant attention to measures to limit the development of floodplains. Once development has occurred and a problem is evident, land use approaches are far less effective. Remedial measures such as retrofitting buildings or relocating development to flood-free sites are expensive and often controversial.

A second problem stems from the fragmented nature of local government in the United States and the fact that governmental boundaries rarely coincide with the ecological boundaries of rivers and watersheds. As a result, unified planning and management of riverine ecosystems, through land use management or other techniques, is difficult to achieve. The federal government attempted to deal with this problem in 1965 through the Water Resources Planning Act, which established a Water Resources Council and, subsequently, several river basin commissions. However, the Water Resources Council never reached its goal of developing detailed plans for river basins—partly because of opposition from the Office of Management and Budget, opposition in Congress where water resource jurisdictions are widely diffused, and partly because of weak nonfederal representation. During the Reagan administration, the various river basin commissions were abolished, and the Water Resources Council, stripped of its staff, ceased to operate.

A third, related factor is that local governments dominate land use policy-making in the United States. While several states (for example, Florida, Hawaii, Maryland, Oregon, Rhode Island, and Washington) have sought to develop and enforce statewide land use planning requirements, most state attention to planning, if it exists at all, is vague, is not prescriptive, and fails to work at the fairly small scale that is required to appropriately address the flood hazard. Local governments jealously protect their powers to regulate land use because local land use is so inextricably connected with quality of life and economic development issues (Peterson 1981; Logan and Molotch 1988). Thus, attempts to improve land use planning and management in a river basin or along a river—or even one or a few reaches of a river—are likely to be severely confounded by diverse local land use practices and preferences.

A fourth problem is the extent to which local government is pressured by economic development needs, land scarcity, or both, to allow development in, or very near, the 100-year floodplain. As noted previously, the NFIP will allow such building if particular construction requirements—habitable floor elevation, for example—are met. Thus, the NFIP does *not* alter land use decisions because it does not call for land use changes—only building practice changes.

Finally, a fifth problem is the belief among landowners that property rights protections are absolute or near-absolute, and that landowners should have the right to use their land in any way they choose, provided it does not unduly hurt others. A number of states have passed property rights legislation in recent years, which may have the effect of dampening local government willingness to employ land use approaches to deal with flooding (Platt 1999, Section II). To date, however, this threat is speculative and has not been verified empirically.

Inducing land use planning change may require either coercion or incentives provided by the state government or incentives provided by the federal government. These could include, for example, a lower, more favorable cost share on nonstructural flood mitigation projects, a lower federal cost share in disaster relief, and changes to the NFIP that actively require planning and discourage building in floodplains except when justified by carefully prepared floodplain management plans. Part of this effort must include improved land use practices that yield both hazard mitigation and ecological benefits. For example, flood mitigation

techniques that would require building away from rivers and floodplains would tend to create improved riparian buffers, which would yield improved water quality and create wildlife corridors through which species can travel (Beatley 2000). At the same time, relying less on engineered solutions can return rivers to flows that more closely follow natural variation.

Regardless of what direction this policy change takes, a fundamental shift is needed to place more responsibility on those closest to the floodplain—first and foremost on floodplain residents and commercial interests; secondly, on local and state governments that exercise land use authority; and, finally, on the federal government.

A considerable amount of progress encompassing most of the foregoing recommendations would result from the enactment of H.R. 1428, the ''Two Floods and You Are Out of the Taxpayers' Pocket Act.'' The National Wildlife Federation testified before a House subcommittee in July 2001 that it supports this legislation because it would increase funding levels for preflood mitigation, including voluntary property buyouts, and would cause flood insurance policyholders to pay actuarial rates for the risks they insure if they refuse a buyout of their property. At the same time, the bill would fully engage the states, local governments, and communities in developing hazard mitigation plans to address repetitive loss and high-risk properties, thereby yielding economic and environmental benefits. However, the most recent Congress, the 107th, did not act on this bill.

Conclusions

The recommendations we make in this paper are not new, but are the product of the collective experience of scholars and practitioners in a wide array of disciplines. Nevertheless, combinations of political and economic factors have prevented their full enactment and implementation. This is due in part to the failure of decision makers to fully appreciate the *environmental* and *ecological* implications of current flood policy decisions. In this paper, we hope to remind the natural hazards community that there is more to the flood problem than the inundation of people and property; there are also the ecological benefits of flooding that must be considered when making policies to protect people and property.

Furthermore, we stress the fact that effective action to mitigate floods and protect sensitive environmental resources requires an active federal role. The most obvious federal actions have been discussed, including changes in flood relief and in the flood insurance program, and a reduced emphasis on structural mitigation. To the extent that federal dollars are involved, federal participation is required to ensure the effective use of federal resources in a coordinated, regional way that recognizes that watersheds and floodplains do not respect political boundaries.

Actual policy implementation, however, will largely rely on the local government. Regional water resource councils would therefore be predicated on participation from the widest range of stakeholders, and coupled with real incentives, such as planning grants and priority availability of mitigation funds. Such actions could induce all stakeholders to begin thinking of floods as relating to a range of land use, water resources, and environmental problems, rather than simply an engineering problem. By thinking broadly, the social, ecological, and economic benefits of comprehensive water management programs are great. Most obviously, this approach will reduce the cost of flood damages. It will also promote recreation opportunities, help shape community consciousness of the importance of water resources, and protect fish and wildlife. Greenways, hiking and bike paths, and parks in floodplains in this way become an important part of the community infrastructure. Stream buffers and natural water storage will reduce pollution, filter water, and promote groundwater recharge, leading to greater availability of good water. Stream buffers may be particularly useful in agricultural areas, where they will reduce the input of phosphates and nitrogen and other pollutants resulting from fertilizers, agricultural chemicals, and animal waste. And these buffers will serve as a habitat for a range of species, thereby promoting species protection and diversity.

The short-term costs of these changes seem daunting, but the likely ecological, social, and economic benefits are great, and the costs can be quickly recovered through savings from flood insurance payouts, reduced disaster relief costs, improved ecosystem functioning, and, perhaps, an improved quality of life that will come with the return of our rivers and streams to more natural flows.

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