From: Ronald J. Daniels, Donald F. Kettl, and Howard Kunreuther (eds.), *On Risk and Disaster: Lessons from Hurricane Katrina*, Philadelphia: University of Pennsylvania Press, 2006, pp. 59-73.

JARring Actions That Fuel the Floods

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The ability of ecosystems to reduce the risks and scales of natural disasters, for example, by attenuating floodwaters and storm surges, has largely been neglected in natural disaster planning and policymaking. Both the 1993 flood on the Mississippi and Hurricane Katrina point to a loss of such "ecosystem services" in the Mississippi watershed, from the northern states down to the Gulf. The actions that cause the loss of these services are often remote from the impacts—whether in time, space, or due to the probabilistic nature of natural disasters. We employ the acronym JAR—Jeopardize Assets that are Remote—to refer to these actions. JARring actions can be taken by private entities or by governments. Policies to prevent such actions are difficult due to the near impossibility of assigning responsibility and to collective action problems since there are so many injured parties, and often many injuring parties as well. JARring actions is a generic concept, and applies whenever remote risks are imposed. They need have no relation to ecosystems or natural disasters, though that is the application in this paper. While the damage (or expected damage) JARring actions cause is often to property, human lives can also be lost and are frequently disrupted from the increased vulnerability to adverse outcomes that JARring actions bring.

This paper assesses two prominent disasters—the 1993 flood and Hurricane Katrina—that were exacerbated by JARring actions. Those actions exemplify our failure to give sufficient attention to ecosystem services that reduce risks. After reviewing these two disasters on the Mississippi and the role of ecosystem services in reducing the risks of such disasters, we turn to the concept of JARring actions, discussing both private and public examples. We then outline a variety of possible policy responses for addressing the external costs associated with the JARring actions undertaken by private entities and by government.

The pictures of a submerged and ruined New Orleans will not soon be forgotten. With over a thousand lost lives and up to a million displaced, Hurricane Katrina left its mark on the nation's psyche. On August 31, 2005, about 80% of the city was underwater largely because levees around Lake Pontchartrain failed. This could have been due to the fact that the levees were only built to withstand a Category 3 hurricane, or due to design flaws or shoddy construction. In any case, what physically caused the failure were high winds, heavy rainfall, and a massive storm surge, that is, water pushed to shore by strong winds. Katrina's storm surge—the difference between the maximum sea level during the storm and the normal seal level—ranged from about 4 to 13 feet along the Gulf Coast. It reached its maximum between Bay St. Louis, Mississippi and Mobile Bay, Alabama where it was near the highest recorded storm surge for that area (National Weather Service Forecast Office Mobile-Pensacola 2005).

The vulnerability of coastal Louisiana, including New Orleans, to Katrina's storm surge was heightened by the loss of coastal wetlands, which naturally buffer storm surges (NOAA 2005). While it is impossible to confidently quantify the extra damage from Katrina attributable to wetland loss, experts agree that wetlands do provide substantial protection. Some indication of this ability comes from Hurricane Andrew. As noted in the Coast 2050 report, a coastal restoration plan for Louisiana, a decrease in storm surge was measured as Hurricane Andrew made its way through Louisiana's coastal marshes. The reduction amounted to a decrease of 3.1 inches in storm surge per linear mile of marsh (and open water) in one site and 2.8 inches per linear mile of marsh in another location, giving total reductions in storm surge of 6 feet and 4.4 feet respectively (Louisiana Coastal Wetlands Conservation and Restoration Task Force and The Wetlands Conservation and Restoration Authority 1998).

While the exact quantitative relation between marshes and storm surges may be imprecise, it is clear that a significant storm buffer has disappeared. Louisiana contains about 40% of the country's wetlands but is also home to 80% of the country's wetland loss; since 1900 over 1 million acres have vanished (Louisiana Coastal Wetlands Conservation and Restoration Task Force and The Wetlands Conservation and Restoration Authority 1998; Stone and McBride 1998; Environmental Protection Agency 2005; van Heerden 2005). Even accounting for several small restoration projects underway, it is estimated that another 513 square miles (a little over 328,000 acres) of land will be lost by 2050 (Barras, Beville et al. 2003). The rate of wetland loss has dropped from a high of about 40 square miles per year in the 1960s to 24 square miles per year today (Britsch and Dunbar 1993; National Research Council 2005). Thus, an area of wetlands close to the size of Manhattan is lost annually off the Louisiana coast, or as the Louisiana Department of Natural Resources puts it, about one football field of wetlands is lost every 38 minutes. This is largely due to the mistreatment of the Mississippi River through private and governmental failure to address the external costs associated primarily with the construction of levees, jetties, and canals.

Inland wetlands also reduce an area's vulnerability to floods. One of the worst floods in U.S. history was the 1993 flood of the Upper Mississippi River, which the National Oceanic and Atmospheric Association estimated flooded 20 million acres in nine states. Damage estimates range from $12 to $16 billion (U.S. General Accounting Office 1995). The flood was triggered by above-average precipitation that saturated the ground, but years of mistreatment of the Mississippi system also played a role. In the nine affected states, 57% of original wetlands had been converted to other land uses or development (Faber 1996). In the Upper Mississippi River basin, flood damage has also been found to be higher in areas with fewer wetlands (National Research Council 2005). While there is not full consensus on whether wetland restoration in the Upper Mississippi could completely handle a flood of the magnitude of 1993, the benefits are quite clear for subbasins and more frequent flood levels (Hunt 1997).

These cases, and many more like them, exemplify the idea of "ecosystem services," a term that has emerged in ecology and spread to the social sciences and to policy discussions. Ecosystem services are the benefits people derive from ecosystems. These benefits can include commodities, like timber and food, or services, such as carbon sequestration, water purification, or recreation. The concept that ecosystems provide benefits to people, and equally importantly, that human actions can deplete these services, dates back to at least Plato. He wrote: "Hills that were once covered with forests and produced abundant pasture now produce only food for bees. Once the land was enriched by yearly rains, which were not lost, as they are now, by flowing from the bare land into the sea. The soil was deep, it absorbed and kept the water" (quoted in Daily 1997). What is new is the growing focus on the economic benefits ecosystems can provide. In this paper, we highlight a particular ecosystem service—the reduction in risk from natural disasters, or an amelioration of the consequences of such events.

Attention to risk-reducing ecosystem services can improve policies to mitigate natural disasters. Previous policy experiments in using ecosystems in this way show that it can be cost effective. For example, the 1970s decision to use wetlands to reduce flood risks along the Charles River in Massachusetts, which flows past the authors' offices, was one-tenth the estimated cost of the dam and levee project that would have stored an equivalent amount of flood water (National Research Council 2004). In addition, the protection of ecosystems can provide additional benefits, such as the protection of habitat for fish, waterfowl, or other species; water purification; and increased recreational opportunities. Finally, ecosystems are not subject to human or technical error. For example, levees around New Orleans have been widely alleged to have had design flaws, or worse yet, contractor malfeasance (Warrick 2005). Commissioned projects that protect against low probability risks are particularly prone to misdesign because we have little experience with the extreme situation creating the risk. Such projects are prone to malfeasance, since the crime is unlikely to be detected. For example, an inadequate levee may not be tested for decades, possibly long after the contractor has left the scene. Mother Nature does not make such mistakes. Of course, the capacity of wetlands to hold water can be overwhelmed, just as levees can be overtopped, but ecosystems continuously function at capacity without human or technical design or maintenance that may go awry, mistakenly or purposefully. To capture the benefits an ecosystem provides they do, however, need to be understood and protected.

JARring Actions

Society continually allows ecosystem services to be lost. One major reason is that the continued provision of risk-reducing ecosystem services is challenged by JARring actions—actions that jeopardize assets that are remote. A JARring action is defined by the fact that it inflicts damage on one or more persons that are distant from the individual undertaking the action; it is a particular type of negative externality. JARring actions are undertaken for the private benefits they bring, as the entity taking the action has no incentive to consider the harm it brings to others, particularly since those others are remote. There is a gulf between the recipients of benefits and the recipients of costs. This gulf is most often due to one of three reasons, spatial or temporal separation, or the probabilistic nature of the imposed costs. These three cases are the focus of this paper.

There are, however, at least two other ways in which costs can be remote from the entity taking the action: First, the impacts of an action can be remote from the political decision to take that action. Most commonly, this occurs when concentrated interests push for privately beneficial but socially wasteful actions that impose modest costs on each of a large number of people (Olson 1990). Second, the impacts can be remote because we do not understand causal relationships; that is, in the case that there are unforeseen consequences, a subject we address below.

Policies to reduce JARring actions are challenged by the very remoteness of the actions from the damage. One reason is that individuals tend to look for proximate causes to events and often fail to investigate remote explanations. A second is that when the externality is imposed on an actor who is far away, or when the damages would occur well into the future, or when the externality is only a hard-to-assess increase in the probability of damages, it is exceptionally difficult to assign responsibility. Thus, there remains plausible deniability to the charge that any particular action

caused or even contributed to the damage. Furthermore, JARring actions are often undertaken by many individuals and the costs are imposed on many individuals, creating collective action problems, severely handicapping the common methods to address negative externalities—contracting, liability, and regulation. This section examines JARring actions taken by individuals or private organizations, notably corporations, and those taken by government, that particularly increase the risks and magnitudes of floods.

As with other negative externalities, private landowners undertake JARring actions because they fail to value the costs of their actions that are borne by others. Self interest dictates such behavior, particularly given that the chances of being penalized are slim. When a private landowner fills a wetland on her property, she decreases the natural water storage capabilities of the entire watershed. This increases the potential flood damage to other residents in the watershed, even if they are in different towns or even states far from her property. Since there is only a probability of a flood in any given year, it is expected damages that have increased. This increase in risk may not be noticed until the next major flood, further removing the affected parties from the individual or corporation who filled the wetlands. In addition, if there is no major flood for many years, those who will suffer damages will be future residents in the watershed who cannot affect current decisions. Finally, with the exception of private entities with extremely large landholdings, the effects of any party's JARring actions will likely be marginal and undetectable by any standard that would hold up in court, even if the cumulative effect of many landowners undertaking such actions is substantial.

There are a variety of inland, JARring land-use decisions that reduce the natural environment's ability to slow and absorb floodwaters. Urban and suburban developments expand the amount of impervious surface cover in a region, increasing the speed of run-off and preventing beneficial infiltration. As just suggested, many small actions, when aggregated, can become significant. John McPhee wrote regarding the Mississippi watershed: "Every shopping center, every drainage improvement, every square foot of new pavement in nearly half the United States was accelerating runoff toward Louisiana. . . . The valley's natural storage capacities were everywhere reduced. As contributing factors grew, the river delivered more flood for less rain" (McPhee 1989).

When development fills wetlands, the natural storage capacity of the watershed is even more drastically reduced. Freshwater wetlands act like a sponge, absorbing floodwaters and then slowly releasing them over time, thereby reducing flood heights. Since 1780, almost 26 million acres of wetlands have been lost in the Upper Mississippi and Missouri River basins. It has been estimated that had they been in place, these wetlands could have stored the 40 million acre-feet of water—enough water to more than cover the state of Georgia with a foot of water—that passed St. Louis during the 1993 flood. Given that a marsh could be around three feet deep in water during a flood, a back of the envelope calculation made by Hey and Philippi (1995) suggested that the wetlands would have been able to accommodate the 1993 floodwaters. Yet, regaining this capacity would not just entail the restoration of an equivalent acreage of wetlands in the basin, but would need to be more strategic. Flood attenuation is determined not just by the total area of wetlands, but by their distribution within the entire watershed (National Research Council 2000), such that flood values are not the same for every acre of wetland (De Laney 1995).

Conversion of natural lands to agriculture also alters the hydrology of a watershed. In the Missouri-Mississippi watershed, agriculture accounts for over 65% of land-use (Hey and Philippi 1995). The grasses of the prairie that once covered much of the Upper Mississippi basin slowed floodwaters, and the rich soil held water and promoted infiltration to aquifers (Hunt 1997). Agricultural lands, however, often are lined with outlet ditches and tile drains to wash water off the land quickly, thereby exacerbating flood risks. Beyond this, the erosion of topsoil has reduced the land's capacity to hold water. (Certain farming techniques, such as conservation tillage, increase water retention. For more on the link between water and soil conservation techniques and flooding, see Hunt 1997.) In addition, an estimated 3 million acres of agricultural lands in the Upper Mississippi are on drained wetlands within the 100-year flood plain (Hey, Montgomery et al. 2004). Finally, farmers along the Mississippi and other rivers often personally invest in agricultural levees to protect their fields from floods; this increases flood heights at the levee and upstream, as the restricted waters back up (although levees are clearly only one of the factors that determine flood heights) (U.S. General Accounting Office 1995).

Coastal ecosystems, including marshes, mangroves, seagrass beds, coral reefs, and sand dunes, protect inland areas from storm surges and erosion. These services can be critical: 43% of the U.S. population lives within 100 kilometers of the coast (WRI 2005). Mangroves reduce erosion by stabilizing the coast and protect inland areas by absorbing storm energy; seagrass beds slow water velocity and thus limit erosion; and coral reefs are a natural breakwater, protecting the shore from erosion by lessening the force of currents and waves (Moberg and Ronnback 2003). Coastal wetlands absorb storm energy and attenuate storm surges, reducing damage to coastal areas, as mentioned earlier. Barrier islands also attenuate storm surges and act as a protective barrier for the wetlands themselves. Coastal landowners may be tempted to build on sand dunes, destroying the first line of defense against storms, or erect seawalls and riprap (rock used to

stabilize shorelines or riverbanks) to protect their own property from the erosive energy of waves, but which can increase erosion for their neighbors (Reddy 2000). In the lower basin of the Mississippi, less than 20% of the original bottomland forest (forested wetlands) still stood in the 1980s, the cutting largely due to conversion for agriculture (Environmental Protection Agency 2005). (Although governmental actions are discussed next, it is important to note that the economic incentive for conversion to agriculture was increased by federal flood-control and drainage projects (Stavins and Jaffe 1990).)

JARring actions on the Mississippi have also resulted from attempts to use a river for commerce. For example, oil companies operating in the Gulf have dredged canals through marshes off the coast of Louisiana, directly destroying wetlands, and also accelerating further damage from erosion and saltwater intrusion into freshwater areas.

The federal government has often been involved. The U.S. Army Corps of Engineers has been improving transportation on rivers since the early 1800s, and the Mississippi is one of the country's major river transportation routes. Canals have been created to facilitate the entry of ships from the Gulf up the river, largely for the benefit of the nation's shipping and grain industries. We thus now turn to public actions more generally.

Just as private entities fail to take account of the remote consequences of their actions, the government can also fail to do so, whether because of a failure to analyze external impacts or due to a neglect of such impacts in response to the pressure of interest groups. The incredible loss of marshland off the coast of Louisiana reflects the convergence of several factors (Britsch and Dunbar 1993). Wetlands require the continual nourishment of sediment. Dam and channel control works constructed in the 1950s halved the total amount of sediment reaching the Louisiana coast (Louisiana Coastal Wetlands Conservation and Restoration Task Force and The Wetlands Conservation and Restoration Authority 1998). The Missouri River had historically been the principal supplier of sediment to the Mississippi, but the construction of five dams for hydropower and irrigation, undertaken between 1953 and 1963 under a joint Corps of Engineers and Bureau of Reclamation plan, all but eliminated sediment from the Upper Missouri River Basin (Meade 1995). The "Big Muddy" no longer delivers as much mud to the Mississippi. In addition, sediment that does reach the mouth of the river is prevented from feeding the marshes by levees that channel the sediment deep into the Gulf. In McPhee's colorful language, the sediment is "shot over the shelf like peas through a peashooter, and lost to the abyssal plain" (McPhee 1989).

This lack of nourishment is exacerbated by the subsidence of New Orleans and the surrounding areas, which creates a high relative rate of sea-level rise that inundates the marshes and speeds wetland loss. The alluvial soils of the delta naturally sink over time unless new sediment restores them. The withdrawal of enormous amounts of oil, natural gas, and saline formation water by oil companies operating in the Gulf have intensified subsidence (Bourne 2004). Finally, the creation of nine major shipping lanes and an 8,000 mile network of canals to facilitate oil exploration (Bourne 2000; Bourne 2004) has degraded the marshlands, increasing erosion and the infiltration of deadly levels of saltwater to those areas of the marsh not directly dredged. The largest shipping canal, the Mississippi River Gulf Outlet (MRGO), was built by the Corps of Engineers to reduce travel time into New Orleans from the Gulf. It bears little traffic, yet has imposed heavy environmental costs—the destructions of 20,000 acres of wetlands, saltwater intrusion in the marshes, and the acceleration of land loss (National Research Council and Committee on the Restoration and Protection of Coastal Louisiana 2005). Before this hurricane season, Hassan Mashriqui, at Louisiana State University's Hurricane Center, predicted that MRGO could funnel and intensify storm surges. It appears that this indeed happened during Hurricane Katrina (Grunwald 2005; Warrick 2005).

The effects of structural flood control projects—the construction of levees, floodwalls, and dams—on the loss of wetlands, and thus their ability to buffer storm surges, are made clear in Louisiana. Structural projects can also alter inland risks. First, such projects often provide a false sense of security, encouraging development behind levees and floodwalls and downstream of dams. When a flood overwhelms these structures, the damage can be quite substantial (for example, see an assessment of the 1979 Jackson flood: Platt 1982). Second, structural approaches seek to move floodwaters off the land quickly. This concentration of water increases pressure on the flood control system, and when a breach occurs a large amount of water rapidly inundates an area, causing more devastation than had the waters been slower and less concentrated (Hunt 1997). Levee construction, which forces water through a narrow area, increases flood heights at the levee and upstream, as mentioned above (U.S. General Accounting Office 1995; Faber 1996; Pinter 2005). This increase in flood heights from levees was observed as early as 1930 (Hunt 1997), if not before. As John McPhee puts it, "Nature was not the only enemy. Anywhere along the river, people were safer if the levee failed across the way" (McPhee 1989), so that floodwaters would spread on someone else's land. The system of flood control levees on the Lower Mississippi River (from Cairo, Illinois to the Gulf) is longer than the Great Wall of China (Meade 1995).

Thus, structural approaches to flood control impose negative externalities on communities upstream and downstream from the project. In Hirsch's metaphor about mass externalities, when everyone stands on tiptoe, all are uncomfortable but no one gets a better view (1976). So too, "structural flood control quickly became its own justification as governments began building one flood-control structure to compensate for the side-effects of another" (Faber 1996).

Of course, some levees, dams, and floodwalls are beneficial investments, particularly those that protect unusually valuable assets. The floodwall at St. Louis, for example, has saved the city and its residents from much damage over the years. Yet, the external costs of altering rivers and coastal lands must enter decision-making. Historically there has been a strong tilt in federal projects toward structural approaches, with little attention paid to the externalities and the long-term or environmental impacts they impose. Happily, this approach is changing (Crosson and Frederick 1999). While the Corps of Engineers originally only undertook navigation and structural flood control projects, in the 1990s, Congress expanded the Corps' mission to include environmental protection and restoration projects as well.

Policy Responses

Individuals do not take account of the external effects of JARring actions when making decisions that fuel floods and often governments fail to do so as well. Vast resources are thereby exposed to destruction. To avoid such waste, policies must be implemented to internalize the external costs that JARring actions impose. Since liability systems and private contracting cannot address the often small and hard-to-detect increment of risk imposed by numerous actors, government intervention is likely required. If transaction costs were zero, the Coase Theorem might assure efficient compensation to keep those who JAR from doing so. However, with myriad affecting and affected parties, and the remote relationship between actions and costs, transactions costs will render private contracting impotent.

Our paper is focused primarily on flooding, but while a focus on flooding and JARring actions—from both the private and public sectors—is quite pertinent following Katrina's devastation of New Orleans, JARring actions have numerous other applications. If global warming proves to be a significant problem in the decades to come, as scientists suggest it will, many greenhouse gas emitting actions we take today, as individuals, corporations, or the government, will come to viewed as the ultimate JARring actions, jeopardizing assets that are quite remote, albeit extraordinarily valuable. While the policies that follow are related to disasters of the Mississippi, this is not meant to suggest that far greater policy challenges for other types of JARring actions do not deserve equal or greater attention.

The most straightforward approach to reduce JARring actions would be direct regulation. Land-use regulation is usually the purview of local governments, some of which already regulate activities such as wetland filling or levee construction. However, localities have no incentive to effectively control JARring actions that have physically distant effects. Moreover, a state may prevent localities from regulating activities the state deems important to its economy, such as transportation or mining, and localities cannot regulate federal and state property (U.S. General Accounting Office 1995). In larger watersheds, such as the Mississippi watershed, local governments will also encounter their own collective action problems. For example, if one local government restricts the filling of wetlands, this will benefit all other localities within the watershed, but if it allows its wetlands to be drained for development, the local community gets all the economic development and taxes. Economic theory therefore predicts that local governments would free-ride on the regulations of neighboring jurisdictions, leading to less regulation and more filled wetlands than would be desirable.

Thus, regulations would need to be undertaken at the state or more likely the federal level, that is, at a level that its jurisdiction embraces both the JARring actor and the parties put at risk. There is precedent for both types of regulation. Five of the nine states affected by the 1993 flood do regulate the construction of agricultural levees (U.S. General Accounting Office 1995). Although not used for this purpose, these regulations could be designed to directly address the externality that levee construction imposes on others in the watershed. The federal government has several programs addressing wetland loss, although none is well targeted for local flood concerns. The programs are either reactive, as with 404 permitting under the Clean Water Act, which regulates the dredging and filling of wetlands by responding to permit applications to allow filling, or opportunistic, as is the Wetland Reserve Program, in which only those landowners that stand to receive private gains enroll; "neither process ensures that the benefits of wetland functions and values are optimized throughout the landscape" (McAllister, Peniston et al. 2000). Another approach would be the creation of a regional entity to coordinate land-use regulations in a watershed. This echoes growing discussion of using the watershed as a unit for policymaking.

A larger barrier to a regulatory approach at any scale of government is likely to be the political opposition it might engender. For example, the Supreme Court has recently agreed to hear cases regarding federal wetland policies (most notably *John Rapanos v. United States*), and in November 2004, opponents of state regulation of private property helped pass Measure 37 in Oregon, which requires compensation to property owners for zoning and environmental regulations.

When direct regulation is politically infeasible, the government could

provide appropriate incentives. For example, JARring actions such as the construction of a levee or filling of a wetland could be taxed or actors could receive subsidies for refraining from taking such actions on their property. Such taxes or subsidies could be administered through property taxes, but other incentives could also be used. For example, development credits granted to private parties could be used strategically to decrease development in floodplains by allowing denser development off the floodplain in exchange (Sheaffer, Mullan et al. 2002). Credits could also potentially be used to encourage development that minimizes increases in impervious surface area and other disruptions to natural drainage. However, for an incentive approach—especially one based on taxes—to provide an efficient level of ecosystem services, or fully internalize the external costs of JARring actions, the government would need fairly accurate estimates of the social costs of each JARring action. That is a hefty information requirement, though once a system was in place information would accrete rapidly. In addition, taxes inevitably meet political resistance. Subsidies for favorable actions would likely be more acceptable, particularly since strongly affected parties dominate most political decisions, and deficit control is not a current political priority.

Fee simple purchase of all the land needed to provide an ecosystem service is another policy option, and one that can prevent JARring actions in perpetuity. This was the instrument used by the Corps of Engineers in the 1970s to preserve wetlands along the Charles River in Massachusetts, as mentioned earlier. If local governments were to attempt to purchase wetlands on their own, in a large watershed such as the Mississippi, coordination problems among various local and state governments in acquiring the necessary land would inevitably make such a policy difficult to implement. The principal argument against acquisition as a primary tool to secure ecosystem services, however, is that it is overkill in most circumstances, hence extremely expensive and inefficient. Since many other land-uses are compatible with ecosystem service provision, the government need not acquire all property rights to the land. Conservation easements are one such alternative to full fee simple purchase that is commonly employed. In acquiring easements, governments could also work in cooperation with local land trusts or groups like the Nature Conservancy, which raise or receive money to acquire land or permanent conservation easements. However, much smaller payments for less severe restrictions might also address the problem.

One potentially attractive policy option is voluntary contracts between the government and landowners, whereby landowners refrain from JARring actions in exchange for payments. Such contracts would need to be for actions that are easily monitored and enforceable. Fortunately, most land-use contracts, such as maintaining a certain amount of one's property as wetlands, would be easy to enforce. Contracts could also be for "contingent services," in which landowners agree to undertake or not undertake particular actions under specified contingencies. For example, they might agree to allow floodwaters to inundate their land in the event of a major flood, thereby saving much more vulnerable or valuable resources elsewhere (on such contracts, see Manale 2000; Hey 2001). The contract could specify the compensation to be paid after a flood, there could be an option payment upfront, or some upfront payment with additional payment later if flooding occurs. One thing is clear: once the waters are rising, it is too late to make the arrangements.

When JARring actions are undertaken by multiple landowners, there would be high transaction costs associated with negotiating the contracts, but having a unified party on the buying side—rather than myriad individuals or localities—reduces the complexities many fold. Institutional arrangements could also likely be arranged to reduce contracting costs. The federal government, could, for instance, announce a price for refraining from a particular JARring action for a period of time. Presumably, the landowners with the lowest costs of provision would be sellers.

The duration of these contracts would reflect a tradeoff between the savings in transaction costs from not having to contract frequently and the benefit of making the future more predictable, against the loss from not being able to respond if conditions change significantly. One possible remedy would be to have permanent contracts, with provisions for buyout. That is, the government might have a per-acre price for permanent preservation of wetlands in an area, which would change every year as better scientific knowledge emerges regarding the risk and as the amount of land under conservation changes. A landowner could buy back her right to develop by paying say a 25% premium on that price. This option protects against the situation in which land becomes very valuable, so that retaining it under conservation for the services it provides is no longer economically rational. (The premium for repurchase also prevents landowners from merely joining the program while waiting to develop their land.)

Contracts of this nature would allow the government to protect the interests of future citizens who would bear costs from the JARring actions of yesteryear. The federal Wetland Reserve Program is based on a similar contracting philosophy—it pays farmers to leave wetlands on their property—but it is not designed to maximize floodwater retention. The use of contracts to address JARring actions falls under the category of "payments for ecosystem services" that have been put in place for other services, such as water quality improvements.

As we have seen, the government often perpetrates its own JARring actions. Policies must be developed to help ensure that the government

addresses the externalities from its own projects. One important step in this direction would be to eliminate the bias toward large structural projects within the U.S. Army Corps of Engineers. The continuous existence of the Corps of Engineers dates back to 1802. The Corps, from the start, undertook both military and civil works projects, although for most of its history it focused on navigation and structural flood control projects. As mentioned above, in the 1990s, Congress expanded the Corps' mission to include environmental protection and restoration projects. For example, the Corps must now consider non-structural solutions to flood control and environmental improvement.

This institutional shift is encouraging the current attempts to improve and include environmental impacts in Corps project assessments. In the past, these analyses were notoriously biased in favor of the large engineering projects the Corps prefers. At times, attention has been drawn to the Corps' shady methods to make such projects look more economically attractive, such as the February 2000 scandal when the Corps was found to have misrepresented numbers in an analysis of a lock expansion project on the Mississippi. As a columnist for Slate noted, the Corps of Engineers "gets away with it because members of Congress and powerful interest groups love water projects, and because few others care about water projects, and because water project studies can be somewhat complex" (Grunwald 2003). To the Corps' credit, it is making a concerted effort to improve its environmental benefits analyses. The incorporation of environmental values into decision-making should be supported and encouraged, as well as should a more holistic approach to project evaluation: "Part of the failure to recognize flood magnification owing to levees is because incremental levee expansion projects are evaluated individually, even when many projects are proposed for a given river reach" (Pinter 2005). This prevents a consideration of cumulative effects leading to "'death by a thousand blows' through the incremental loss of floodplain land to development" (Pinter 2005).

The JARring actions that are most difficult to address politically are those whose impacts are distant in time and also unforeseen. An early example is the 1850 Swamp and Overflow Land Act, which deeded swamps to the states. As McPhee summarizes, "these river swamps had been the natural reservoirs where floodwaters were taken in and held, and gradually released as the flood went down. . . . The new owners drained much of the swampland, turned it into farmland, and demanded the protection of new and larger levees. At this point, Congress might have asked itself which was the act and which was the swamp" (McPhee 1989). While the value of these swamps as natural flood control reservoirs is clear now, at the time filling them for agriculture appeared the most productive policy. Similarly, when extensive canal building by oil companies in the Gulf began many decades ago, the long-term consequences were not fully understood. When time-distant consequences were unforeseen, it is usually not possible retroactively to secure compensation or remediation. Correcting for the damages of past actions will thus remain a needed policy at times.

Though preservation has vast cost advantages over restoration—a dime of prevention is worth a dollar of cure—some situations are so dire that highly expensive and politically challenging restoration must be considered. The coastal marshes of Louisiana represent such a situation. Several restoration projects are currently underway, including projects under the Federal Coastal Wetlands Planning, Protection and Restoration Act (The Breaux Act); two large diversion projects to bring Mississippi sediment back to marsh areas—the Caernarvon and Davis Pond Freshwater Diversions; and the Coast 2050 effort. Coast 2050 is a multi-stakeholder endeavor to develop a comprehensive restoration plan for Louisiana's coastal wetlands (see Louisiana Coastal Wetlands Conservation and Restoration Task Force and The Wetlands Conservation and Restoration Authority 1998). Construction of the Coast 2050 plan would cost about $14 billion.

Before Hurricane Katrina, full funding for the Coast 2050 effort did not receive political support, but disasters focus the mind, or at least the political process. Compared to the costs of Katrina, the $14 billion required may now seem a more attractive investment. Quite apart from the monies involved, rebuilding the coastal marshes of Louisiana is politically difficult since the various interests in the Gulf—shipping interests, oil companies, fishermen, farmers, and coastal communities—can often be at odds. Coast 2050 makes an effort to develop a consensus among as many stakeholders as possible to get full support for its projects along with other recovery efforts.

Restoration efforts also occur on a smaller scale. Both Napa, California, and Reno, Nevada are undertaking flood projects that involve wetlands restoration. The local governments, in partnership with federal agencies, have acquired land and have let their rivers return to their natural floodplain. When land along a river is not already highly developed, this can be an attractive option for smaller scale flood control that also provides additional benefits to the communities, such as a more attractive riverfront, recreational opportunities, less polluted rivers, and habitat for fish and birds.

Conclusion

JARring actions have reduced the ecosystem services that protect communities from such natural hazards as floods and storm surges. Individuals, companies, and even governments fail to account for the costs their actions impose on those who are remote from them, leading to outcomes that are suboptimal for society as a whole. Addressing the externalities of JARring actions is challenging due to the remoteness of those undertaking actions from those affected, the large number of affected parties, and often the large number of entities taking JARring actions. Yet the challenge must be met or we will continue to put assets including, most importantly, human lives and livelihoods, at risk. While we can never contract with the future or accurately predict all of the consequences of our actions and policies, policymakers must extend their thinking about their impacts beyond the local, the near term, and the likely. They must recognize that watersheds are interconnected systems, and that actions in any part of them, for example on any part of a river, may have consequences elsewhere in the system. As John Muir wrote, "When we try to pick out anything by itself, we find it hitched to everything else in the Universe" (Muir 1911).

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