AN ECOLOGICAL SOLUTION TO THE FLOOD DAMAGE PROBLEM

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Abstract

We must reconsider how our floodplains are used in the face of increasing, catastrophic flood damage and public investments in flood control. Wetland restoration can effectively and efficiently return basic floodplain functions: holding floodwaters, improving water quality, and supporting biodiversity. Both the 1993 and 2008 floods on the Mississippi River above Grafton, Illinois could have been contained within a small portion of the 100-year floodplain with little flood damage. Low-tech restoration of the river channel and floodplain would result in one to five-million acres of wetlands. For example, the 1993 flood would have occupied 33% of the 100-year floodplain above Grafton, Illinois, while the 2008 flood would have occupied only 7%. The peak discharge would have been reduced by 64% in the case of the 1993 flood and by as much as 78% of the 2008 flood. The wetlands, needed to safely store the 1993 floodwaters, the larger of the two floods, would occupy 4.5 million acres, or 4% of the total watershed area. The annual net social benefits, including flood damage avoidance and recreations, would be $500 million.

Introduction

Within the last year, the papers and airwaves around the world once again have been inundated with reports of flooding and consequent human loss and suffering. From Iowa to India, floodwaters have swept away human lives and possessions illustrating the shortsighted and costly practice of developing floodplains for residential, commercial, industrial and agricultural uses. The risks of floodplain development are well known; the failures of structural protection are well demonstrated; the social costs of flooding are enormous. How are we going to reform our use of floodplains?

In the United States, we have experienced catastrophic flood damage for well over 150 years and spent billions of dollars in attempting to stem flood losses. Yet, our flood losses have continued to grow, in terms of constant dollars, and have continued to far exceed our flood control expenditures. The floodplain drama continues ad infinitum: a cycle of human development and occupation, failed flood control projects, economic losses, and human suffering. Given the long and painful history of flooding in this country and around the world, why have we not adopted more effective ways to reduce flood damage? Is there no end in sight? Cannot the deleterious effects of flooding be reduced? The answer to these questions is a simple yes. There is hope! All we need do is to incorporate in our flood management logic this simple syllogism:

- *Land use controls the nature of topographic and structural changes to our floodplains, which affect the detention and discharge of water;*
- *Economics controls land use;*
- *Therefore, economics controls flooding and flood damage.*

Applying these three premises to *all* floodplain development will radically change the nature of such development, and it will change the magnitude of flooding and corresponding flood losses. The solution corollary that follows the syllogism is:

• *If economics controls the causes of flooding and flood damage, then it can solve the problems.*

If economics is to control, then all development on the floodplain must bear the full cost of the development activity with no governmental subsidies (*e.g.*, crop support, flood and crop insurance, tax increment financing, construction and repair of flood control structures, and related emergency services) and no cost externalization. In other words, all real and potential damage caused by displaced floodwaters, sediment or any other natural resource must be internalized in the capital and operating costs of the development. The magnitude of the related external costs is illustrated in Figure 1. Since 1934, the federal government has spent $160 billion on flood control projects while floodplain users have suffered $390 billion in losses nationwide. The sum of flood losses and flood control expenses yields the external cost of floodplain development: $550 billion.

What effects will the application of the syllogism and its corollary have on floodplain development and external costs? First of all, the application will greatly increase the cost of floodplain development and, thereby, reduce the capital structures or economic activities on floodplains. This, in turn, will reduce future flood damage by eliminating floodplain "improvements." Secondly, it will provide the economic incentives necessary to drive wetland restoration by creating the financial means to strategically restore lost flood storage and, in sufficient scale, to compensate for existing floodplain developments that cannot be moved or abandoned. As argued below, sufficient lands are available and the costs of restoration are justifiable by the reinstated ecosystem services (*e.g.*, flood storage credits, water quality credits, carbon credits, etc.). The 1993 and 2008 floods in the Upper Mississippi River Basin should serve as adequate impetus for restoring the floodplain and the associated wetlands.

Background

The landscape of the Upper Mississippi River Basin (UMRB) was once comprised of a diverse system of tall grass prairies, savannas, hardwood forests and wetlands. Over the past 200 years, logging, farming, river transportation and urban development have transformed nearly 80% of the basin, including the conversion of 67% of the basin to managed agricultural lands (UMESC, 2007; National Audubon Society, 2000).

This development included drainage of more than 30 million acres of "wet soils" within the UMRB, including the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin (Zucker and Brown, 1998). Thousands of miles of tile were laid, agricultural outlet ditches constructed and low order streams channelized. More than 80% of the drained land is now in row crop production (Zucker and Brown, 1998).

Further modification of the natural system occurred as a result of the Flood Control Act of 1928. This Act provided federal support to build, enhance and extend levees, which were designed to prevent

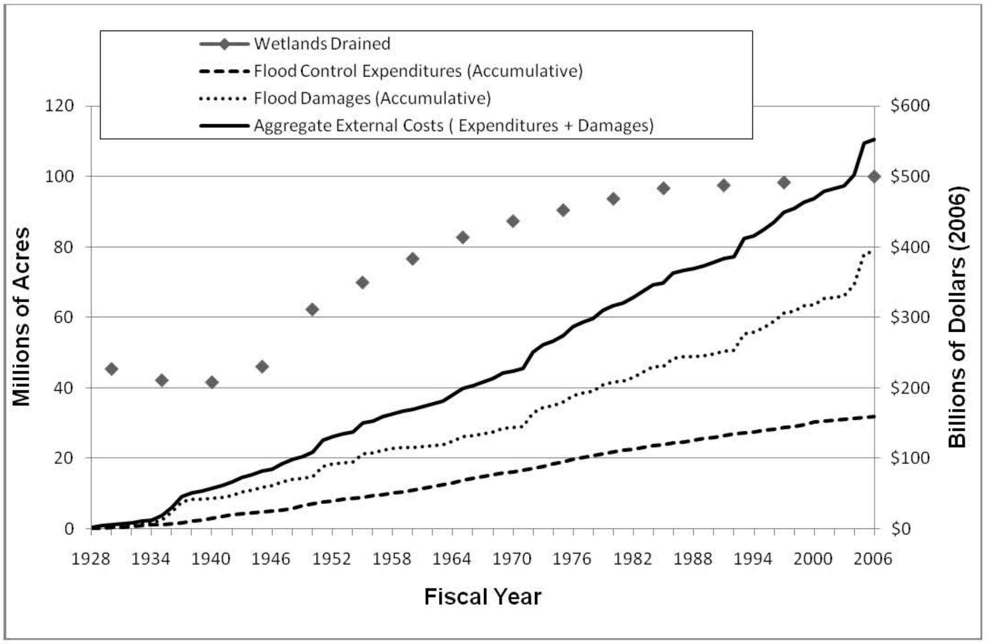

Figure 1. National wetland loss and flood damage costs compared to ACOE expenditures adjusted to 2006 Dollars using Construction Cost Index EM 1110-2-1304. ["Millions of Acres Drained" were interpolated from a total of 100 million acres lost by 2006 and the rate of loss reported in the Mississippi River Basin over the same period (Dahl, 2000; Rabalais *et al.*,1999; Goolsby *et al.*, 1999; USDA 1987). "Accumulative Expenditures" were adjusted to 2006 Dollars with the 2005 and 2006 values interpolated from previous trend (USACOE, 2005). "Accumulative Flood Damages" were adjusted to 2006 Dollars (NWS, 2006).]

floodwaters from reaching their natural storage areas- the floodplains. In addition, floodways were created to pass excess flow in critical areas, and channels were improved and stabilized to increase hydraulic capacity and river navigation. In the entire UMRB, over 2 million acres of floodplain land, or so called bottomland, are isolated from their dependent rivers by federal levees (Hey *et al*., 2004).

As the artificial drainage and flood protection systems spread across the landscape, the natural, ecosystem services of our rivers and their floodplains declined. Many of the extensive freshwater wetlands and riparian zones once naturally associated with the streams and rivers of the UMRB were destroyed (Mitsch *et al*., 2001). The loss of wetlands throughout the basin has increased the problems associated with flooding: loss of life and human suffering, property damage, and sediment and contaminant transport through the drainage system and ultimately into the Gulf of Mexico. These damages have been steadily increasing over the past 200 years, despite the ever increasing investment in structural controls (Figure 1).

Floods of 1993 and 2008

The "Great Flood of 1993" was one of the most destructive and the costliest flood in the history of the United States (Johnson *et al*., 2004). This flood was unique in regards to the number of record stages reported throughout the basin, the area impacted, and the duration of the event (nearly 200 days in some locations; Larson, 1996). Nearly 150 major rivers and tributaries were affected and 1,000 federal and non-federal levees were topped or breached inundating over 256 million acres across 9 states (Larson, 1996; Johnson *et al*., 2004). As a result, 50 people were killed, 70,000 people were evacuated, at least 75 towns were completely under floodwaters, 50,000 homes were damaged, water and wastewater treatment facilities were destroyed, and at least 15 million acres of working cropland were flooded (Larson, 1996). Economic damages were nearly $15 billion (Larson, 1996).

In 2008, there was a smaller but similar flood event on the upper Mississippi River and many of its tributaries (*e.g.*, Cedar, Des Moines, and Wisconsin Rivers). Again, flood stages exceeded record levels in many areas. While the final statistics have not been released, dams and levees (at least 20) were breached across parts of Wisconsin, Iowa, Indiana, and along the Mississippi River; 40,000 people were evacuated; and 2-5 million acres of farmland were damaged (O'Connor and Davey, 2008; Achenbach, 2008). Preliminary estimates put the damages at several billion dollars.

While both floods caused significant damages, by all measures, the 1993 event had a greater spatial extent and duration. The 1993 flood resulted from a prolonged period of persistent precipitation, starting in March and extending through most of August throughout the upper Mississippi and lower Missouri River basins. The major rains were in June and July with the most significant flooding occurring later in July and August as heavy rains continued throughout the region. The precipitation event causing the 2008 flood centered over the upper Mississippi River, north and east of the Missouri River basin. The flood was the result of not only record rainfall in June but the precipitation across the UMRB from December 2007 through May 2008, which was the second wettest six month period on record. Since the region was already saturated, the majority of the June precipitation drained directly into the tributaries of the Mississippi River (NOAA/National Climatic Data Center, 2008).

To further characterize and compare the two events, the discharge and stage data from the United States Geological Survey's stream-flow station at Grafton, Illinois (USGS 05587450), were used (Table 1). This gage station has a drainage area of 171,300 mi^2 (109.6 million acres) (USGS, 2008) including the Illinois River but excluding the Missouri River (Figure 2). The maximum discharge for the 1993 event (596,000 cubic feet per second, cfs) was 1.4 times greater than that of the 2008 flood (431,000 cfs) (Tables 2 and 3). The number of days for which the discharge exceeded the station's minor flood-stage was 151 during the 2008 flood, compared to 216 days of flooding during the 1993 flood. In 1993, assuming that all of the water discharged above the station's minor flood level could have been stored upstream, 54 million acre-feet of storage would have been required (Table 2). If the floodwater had been stored in wetlands at a 3 foot depth, 18 million acres would have been needed. By comparison, the 2008 flood would have required 22 million acre-feet of storage and 7.4 million acres of restored wetlands (Table 3). This flood storage strategy would utilize from 54 to 161 percent of the 100-year floodplain, as designated by the Federal Emergency Management Agency (FEMA; Table 4). A less land intensive effort would be to store floodwaters above the moderate

Table 1. NWS Flood Stages and Discharges for the Mississippi River at Grafton (USGS 05587450).

Flood Stage	Minor	Moderate	Major
Stage (ft)	18	24	29
Discharge (cfs)	212,000	336,000	380,000

Table 2. Calculated flood data for Mississippi River at Grafton during 1993 flood period of analysis: 10/12/1992-10/11/1994.

Flood Stage	Minor	Moderate	Major
Main flood event period[1]	3/7/93-10/9/93	6/29/93-10/6/93	7/7/93-8/17/93
Main flood event duration (days)[2]	216	100	42
Max. recorded discharge (cfs)	596,000	596,000	596,000
Max. total flood storage (acre-ft)[3]	53,518,000	13,444,000	9,360,000
Max wetland area during event (acres)	17,839,000	4,481,000	3,120,000
Event flood storage duration (days)	543	145	100

[1] The flood event period was based on the discharge exceeding flood discharge listed in Table 1.
[2] The number of days within the flood period.
[3] Assuming a storage depth of 3 feet.

Table 3. Estimated flood data for Mississippi River at Grafton during 2008 flood period of analysis: 9/28/2007-9/27/2008.

Flood Stage	Minor	Moderate	Major
Main flood event period (discharge)[1]	3/18-8/5	6/15-7/8	6/18-7/7
Main flood event duration (days)[2]	151	24	20
Max. recorded discharge (cfs)	431,000	431,000	431,000
Max. total flood storage (acre-ft)[3]	22,098,000	2,937,000	1,132,000
Max wetland area during event (acres)	7,366,000	979,000	378,000
Event flood storage duration (days)	3/18-to date	41	26

[1] The flood event period was based on the discharge exceeding flood discharge listed in Table 1.
[2] The number of days within the flood period.
[3] Assuming a storage depth of 3 feet.

Table 4. Extrapolated Upper Mississippi River Basin floodplain land cover in million acres (Hey *et al*., 2004).

State	Bottomland: 100-Year Flood Zone	Cropland in Bottomland[1]	Pre-settlement Wetland: Hydric Soil	Current Wetland on Hydric Soil[2]	Cropland on Hydric Soil[1]	Grassland on Hydric Soil[3]
Illinois	2.36	1.20	1.01	0.17	0.74	0.05
Iowa	6.95	2.82	2.22	0.25	0.94	0.49
Minnesota	2.31	0.34	1.27	0.50	0.18	0.14
Wisconsin	2.01	0.58	0.92	0.50	0.28	0.05
Total	13.60	4.92	5.41	1.42	2.13	0.73

[1] Includes corn, soybeans, winter wheat
[2] Includes water, wetland, and wet forest areas
[3] Includes rural grassland

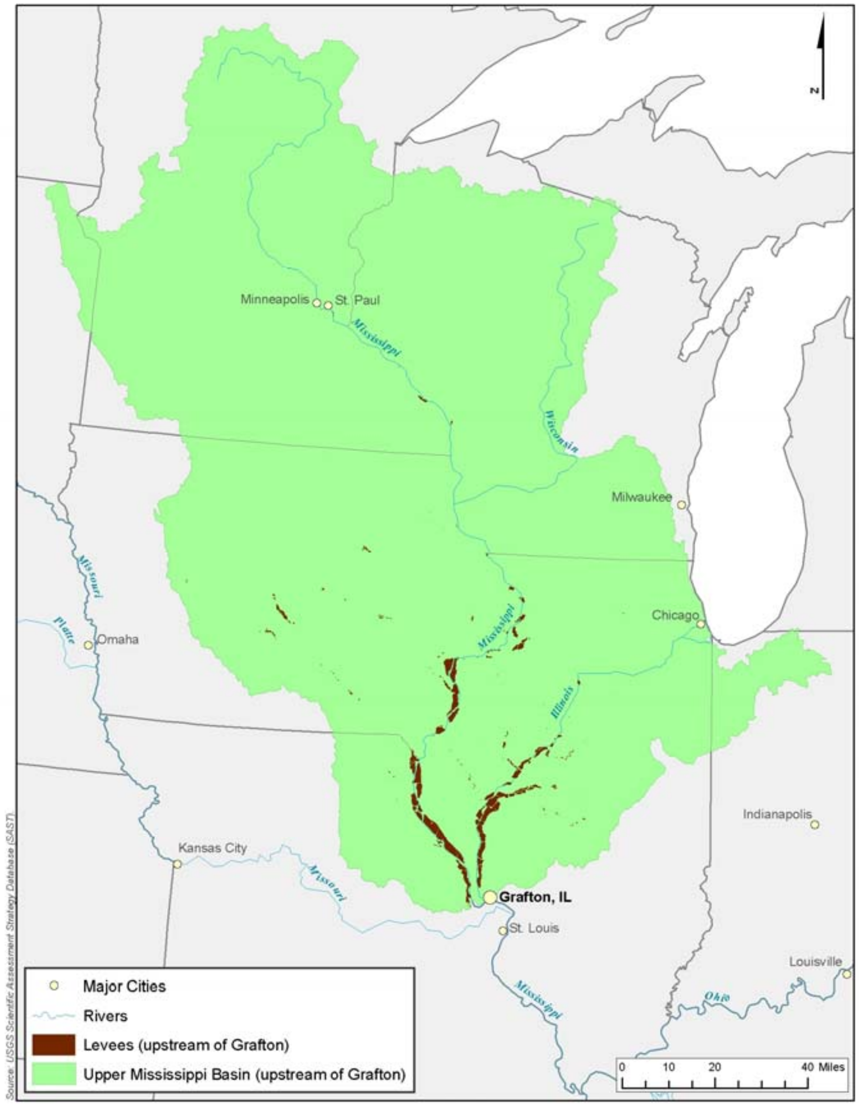

Figure 2. Leveed areas within the Upper Mississippi River Basin north of Grafton, IL.

flood stage at Grafton. For the 1993 event, 4.5 million acres of wetland would have been needed with a much smaller area, 979,000 acres, for the 2008 flood. Thus, 33 to 7% of the FEMA floodplain would be required for flood storage. Even so, are there suitable lands available for flood storage?

Where are the lands?

In 2002, the Wetlands Initiative conducted a study funded by the McKnight Foundation on the potential flood storage areas in the UMRB. For the basin above the Missouri River, the results indicated that today approximately 4.92 million acres of bottomland/floodplain are being used for agricultural production (see Table 4). This accounts for approximately 36% of the 13.6 million acre 100-year floodplain.

If, instead, all economically valuable activities (*i.e.*, cropland, shopping malls, roads, etc.) were removed from the bottomlands, then the entire 13.6 million acres of 100-year flood zone could be used to store floodwaters, rather than forced to hold floodwaters as happens in a major flood. Low external-levees, cross-levees and overflow and backflow structures would be necessary to divert, trap and release the floodwaters. Using the bottomlands with a 3 foot water depth, all of the floodwaters above the moderate flood level in 1993 could have been safely stored (13.5 million acre-ft). Approximately 75% of all the water above the minor flood stage could have been retained. In truth, the floodwaters of both the 1993 and 2008 events were stored on these lands in one configuration or another, but they unfortunately inundated the existing corn and soy bean fields, among other things. Storing this amount of excess floodwater on the land, rather than moving it rapidly off the land, would significantly reduce the amount of flood damages incurred further downstream, all the way to the Gulf of Mexico.

Restoring the 13.6 million acres of floodplain would have a positive impact on the economic health of the region. Agricultural economist Tony Prato of University of Missouri-Columbia calculated the annual social benefits and costs that would result from converting all of the cropland within the 100-year flood zone to wetland (reported in Hey *et al*., 2004). This conversion would result in a total estimated annual net benefit of $1.4 billion, indicating that conversion of the existing cropland to wetland in the flood zone is socially cost effective. In Prato's study, social benefits included: the annual reduction in flood-related crop damages; governmental crop subsidies; and, non-flood related benefits. Social costs included: the loss in farm rentals; wetland restoration; and, operation and maintenance.

Conclusions

Given that the floodplain is modified, wetlands are restored and all flood flows less than or equal to the moderate flood discharge are released downstream, the 1993 flood would have occupied 33% of the 100-year floodplain above Grafton. The 2008 flood would have occupied only 7% of the floodplain. The peak discharge would have been reduced 64% in 1993 and as much as 78% in 2008. For the UMRB watershed above Grafton, the flood-storage wetlands would occupy less than 4% of the total watershed area and require a minor or negligible reduction in agricultural production. The capital cost for this level of flood control could be as much as $2.0 billion, while the annual net social benefit would be $0.5 billion including flood damage avoidance and recreation (derived from Prato's calculations in Hey *et al*., 2004). The social benefits would be increased if nutrient management (nitrogen, phosphorus and carbon credits) were included. The proposed ecological strategy is a more effective, efficient, sustainable and fair means of flood damage reduction in comparison to traditional approaches, such as levees and dams.

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