

Preparing for a Chaotic World: Redesigning the Nation's Flood Control and Emergency Response Systems

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Introduction

The devastation wrought by Hurricane Katrina revealed failures across an array of human institutions in crisis preparedness, response and recovery. These institutions included federal, state and local agencies, as well as private health care providers and firms involved in energy, the environment, and telecommunications. Analyses of the disaster generally emphasize the internal shortcomings of specific organizations. But not only were individual groups clearly overwhelmed, there were also critical breakdowns in collaboration and coordination.

Moreover, the organizational problems did not begin when Katrina made landfall. The flood control system itself was a patchwork of projects with little in the way of systematic, rigorous planning. The fault for this does not lie with individuals, but with the poorly organized system of planning for flood control.

If Katrina was a “one of a kind” event, then what went wrong would be relevant only for assigning responsibility. But in fact, Katrina may be far from unique. For example, Sacramento is also considered to be highly vulnerable to flooding on a similar scale, while the possible collapse of the levees system in the nearby Delta area could imperil much of California's water supply. More generally, complexity theory teaches us that low-probability but high cost events are a predictable possible outcome of complex systems (such as oceans, weather, and ecosystems). We need to revamp our approach to these problems in light of what we know from complexity theory.

Fortunately, we are beginning to learn how to address issues of this kind. It will take considerable planning to address these issues, but we can already identify three key elements of such a plan:

- *Reengineering the Army Corps of Engineers.* The Corps' ability to do its job has been handicapped organizationally. It does not have the benefit of outside expert review of its flood control projects; its engineering and R&D capacity has suffered in recent years; flood control and environmental planning have been

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disconnected; and it has failed to coordinate effectively with state and local government as well as other stakeholders. All of these issues must be addressed. Moreover, a new computer technology, Geographic Information Systems (GIS), could be used to help integrate flood control and ecosystem planning.

- *Creating an effective system of disaster planning.* Here, what we need is to convert FEMA into a High Reliability Organization, just like a nuclear submarine or air traffic control; we need to establish a National Disaster Advisor within the White House; and we need a Congressional Office on Catastrophic Risks.
- *Using GIS Technology to Dispel the “Fog of Disaster.”* Planning for disasters is difficult because the relevant information is scattered among many officers and buried in archives; responding to disaster suffers from the same handicaps augmented by the stress of emergency response; rebuilding suffers from the difficulty of modeling complex land use and infrastructure plans. GIS has the capacity to address all of these issues.

These changes will not necessarily be easy to implement, nor are they a cure-all. But they do provide some sense of the direction in which we need to begin to move, if we are to avoid the well-known fate of those who refuse to learn from history and are therefore condemned to repeat it.

Chaos, Catastrophe, and the Environment

Notwithstanding our best efforts at prediction, from time to time the world presents us with nasty surprises. Freak events of this kind present a dilemma to policymakers. It would be paranoid to assume that the worst will always happen. Yet, perhaps paradoxically, it is reasonably foreseeable that non-reasonably foreseeable events will occur from time to time. A planning process that ignores this reality will work satisfactorily nearly all of the time, but when failures do occur they may be catastrophic. The overwhelming majority of the Lincoln family's theater outings went smoothly, but Mrs. Lincoln doubtless took little comfort from this observation.

Environmental regulation has grappled with this problem for several decades. This essay assesses those efforts in light of the developing theory of dynamic systems, sometimes called complexity theory or chaos theory. One lesson of complexity theory involves the peculiar statistical behavior of complex systems. Even people who have never heard of a bell curve (a/k/a normal distribution) have an intuitive sense of its properties, with most events bunched near the average and extreme outcomes fading away quickly. If the average cat weighs ten pounds, we can expect that most cats will be within a few pounds of the average, and we can safely disregard the possibility of a two-hundred pound tabby. But complex systems are often characterized by a different kind of statistical distribution called a Power law. (Schroeder, 103-119). If cats' weights were subject to a power law, we would find that the vast majority of cats were tiny or even microscopic, but that thousand-pound house cats would cross our paths now and then. Under a power law, the possibility of freak outcomes (a one-ton Siamese) weighs heavily in the analysis, often more heavily than the far more numerous routine outcomes (the tiny micro-cats). The

harmless kittens that litter your path would be much less of an issue than the enraged saber-tooth you might encounter once in a lifetime. Indeed, a power-law probability distribution makes it somewhat misleading to even talk about the Atypical@ outcome, given the huge range of possibilities.

Ecological thought has moved away from the idea of equilibrium toward a more dynamic vision, as Bosselman and Tarlock explain:

[E]cology is following physics as it owes much to chaos theory. Non-equilibrium ecology rejects the vision of a balance of nature. Change and instability are the new constants. . . . Ecosystems are patches or collections of conditions that exist for finite periods of time. The accelerating interaction between humans and the natural environment makes it impossible to return to an ideal state of nature. At best, ecosystems can be managed rather than restored or preserved, and management will consist of series of calculated risky experiments. (Bosselman & Tarlock, 879-880)

Rather than following the familiar normal distribution, the Abell curve,@ outcomes in complex systems often follow what are called power lawsCthat is, the frequency of an event is often given by its magnitude taken to a fixed negative exponent. A classic example is given by earthquakes. Other examples include the size of extinction events, the number of species present in a habitat, or the size of the Nth smallest species (meaning that almost all species are rare but a few have very large populations).

What all of this adds up to is that the world behaves less “normally” than we would expect. We are lulled into complacency by a host of small events, assuming that larger events will be on the same scale. We get used to hurricanes as an annual, almost routine event in parts of the country. Then Katrina comes along.

We need to adjust our planning to deal with a chaotic world. Systems that are designed for the routine or the slightly surprise will not hold us in good stead when the catastrophic happens. Katrina provides us an example of this, which we should not forget – but which we are likely to forget over time, unless we take steps to build long-term institutions based on this insight.

Building Institutions for a Chaotic World

Many institutional processes are designed to eliminate variance by fine-tuning techniques. We hope to perfect repetitive tasks like manufacturing to “six sigmas,” eliminating all variability of outcome through a perfectly honed production process. Even where risks are necessarily present, we seek to routinize the process of risk assessment and risk management through techniques such as cost-benefit analysis. All of these techniques are valuable, but they have their limits and can sometimes have counter-productive side-effects.

In a world characterized by complexity, we have to begin by admitting the impossibility of perfecting what we are doing. Perfection requires stability – the notes in a Beethoven score never change, so it is possible to aspire to a perfect performance. But many of the problems that we encounter are more like a jazz improvisation with unpredictable changes in the players, instruments, and styles. Rather than perfecting the playing of each individual note, we need to be alert for new information that may change old answers; we need to realize that planning must be flexible; and we must avoid locking ourselves into decisions that may later prove misguided. And we also need to be able to enter into shifting partnerships with other organizations, as the scope and dimension of the problem and the need for expertise and resources shift.

There are actually some successful examples of such institutions, such as the nuclear Navy built by Admiral Hyman Rickover. (Duncan 2001). Organizations that cannot afford failure cannot limit themselves to routine risks or even to those that have materialized somewhere in the past. They have to be alert to uncertainties, to surprising events that may shed light on future risks, and to smaller mistakes that indicate the need for reengineering human and technological systems.

Reengineering the Army Corps of Engineers

It is no secret that the New Orleans flood control system was deeply and fatally flawed. Most of the blame does not go to any specific individual or group of individuals, but rather to an organizational structure that made it difficult for good decisions to be made and implemented. Fixing the technical problems will have only limited impact unless we also fix the organizational problems.

An ideal solution might be a National Flood Defense Authority, which would be charged with oversight over the construction and maintenance of levees and other infrastructure. The USACE, state flood control authorities, and a new technical advisory board would work with the NFDA to coordinate efforts and planning.

Short of the creation of such a new agency, much could still be done to improvement the organization and performance of the flood control system. Specifically, Congress should consider three recommendations.

- Review of flood control projects by independent experts,
- Rebuilding the USACE's engineering and R&D capability,
- Integrating flood control and environmental planning,
- Restructuring the federal/state relationship in flood control.

These three recommendations would go a long way toward repairing the Corps's ability to design and build effective flood control projects.

Review of Flood Control Projects by Independent Experts

Three years before Katrina, the National Research Council concluded that the “Corps’ more complex planning studies should be subjected to independent review by objective, expert panels.” (NRC 2002, p. 70). This is an obvious point – which makes it all the more urgent to implement it.

Although the need for independent project review has been apparent for several years, none of the past proposals have yet been implemented. Before the nation invests billions of dollars in the South Louisiana flood system, it is imperative that a peer review process be put in place. Legislation currently pending in Congress will help to address this issue.

Rebuilding USACE Capacity

The USACE’s engineering and research capabilities have been degraded over the past twenty years as a result of streamlining and budget cuts. As a nation, we cannot afford the loss of this expertise. Although outsourcing can be efficient, it cannot be allowed to deplete USACE’s own core expertise. As the National Research Council concluded, “Shifting analytical tasks to the private sector, however, has its limits, as core, ‘in-house’ competence is necessary for the Corps to commission, manage, and comprehend the advice of external experts.” (NRC 2004, p. 72)

The Army Corps of Engineers must be, first and foremost, the nation’s premiere expert in flood control engineering. Through no fault of its own, the Corps has been stripped of much of what it needs to perform this role. Congress must adopt a plan and allocate the necessary funds to “put the ‘engineer’ back in the Corps of Engineers.”

Integrate Flood Control and Environmental Planning

We know that the planning process has failed badly:

- a. The engineering analysis badly underestimated the potential for a large hurricane to hit the city. I’ll leave to others the question of whether this was just a mistake. But at least, there should have been a margin of safety to allow for uncertainty about the size of the risk.
- b. At the urging of OMB and CEQ, the White House demanded that the Corps implement only 10% of the recommended funding for the Coast 2050 plan.
- c. Wetlands destruction continued despite laws designed to protect them.
- d. The government has completely ignored the risk that climate change might pose to the Gulf Coast.

It is well-known that Louisiana's coastal barriers and wetlands provide natural buffers against hurricane surges, although it is impossible to know the extent to which they might have deflected harm from any one storm. Mangrove forests played a similar role in protecting some areas of Asia from the tsunami. Moreover, the Berkeley/NSF engineering team investigating the failure of the New Orleans levees discovered that levees protected by nearby wetlands fared much better. USACE is also involved in wetlands preservation and restoration efforts. However, those efforts have proceeded in isolation from its flood control mission. The two need to be integrated.

Another reason to integrate these missions is that flood control projects often raise environmental concerns. These need to be addressed in a comprehensive way during the planning process, not merely deferred until a separate environmental review process.

Using GIS to Aid Planning

Our society better integration of its flood control and environmental planning. Some of the changes involves are obviously organizational, but technology may be able to help as well. Earth.Google.com promises to create a "globe inside your PC." Current technology would allow the more modest goal of putting key watersheds like Southern Louisiana "inside your PC." Consider what it would be like to have instant access to everything we know about the Louisiana wetlands and flood control system. We can already begin to see the outlines of such an information system, which would provide "one-stop shopping" for all environmental information. Current and historic information about urban development, water flows, animal and plant populations, soils, levees, potential storm surges and ecosystem characteristics would be available through a single interface. Rather than consideration of environmental impacts being shunted off to a special reporting process, it would be an on-going, publicly accessible process.

It was a major step for environmental awareness when people were able for the first time to see the globe from space. It would be another major step if they could see grasp the regional environmental as a whole, zooming in to inspect local environmental conditions and back out again to see larger trends. Humans are visual animals, and we can only fully appreciate that which we can see.

A GIS system of this kind would make it much easier for planners, policymakers, and the public to see the interrelationships between planning decisions, flood control structures, and wetlands development (or restoration). Although the technology may seem futuristic, it is well within reach.

Keeping on an Eye on the "Worst Case"

Complexity theory has mixed implications for worst case analysis. On the one hand, a power law precludes the possibility of a genuinely worst case: there are always even worse (though even less likely) cases to worry about. So critics of worst case analysis were right to worry about the arbitrariness of selecting a single Aworst@ case. On the other hand, one characteristic of power laws is that the unlikely events on the right tail of the curve have a strong cumulative effect. If we focus only on what seem to be reasonably likely outcomes, we overlook the statistical possibilities for nasty surprises.

Worst case analysis can be a useful reminder that through a string of unlikely coincidences, things may go very wrong indeed. Despite the tiny likelihood of any one such freakish outcome, the total spectrum of extreme outcomes may deserve serious weight in the decision. Consideration of the worst cases—more accurately, of a spectrum of possible worse cases—can compensate for the tendency to focus too heavily on the likely outcomes of an action and dismiss speculation about possible disasters.

At one time, CEQ's NEPA regulations mandated a formal "worst case" analysis. The general consensus is that this requirement was burdensome for agencies and potentially misleading for the public. We do, however, need to be careful to plan for reasonably plausible though unlikely outcomes. We also need to keep in mind the existence of critical uncertainties. For example, in planning the New Orleans flood control system, the Corps seems to have assumed that weather patterns would be static. As we now know, hurricane frequency is probably cyclic and there is probably a long-term upward trend in intensity due to climate change. Much of this could not have been foreseen when the planning decisions were made. But what was foreseeable is that our knowledge of weather patterns might be unreliable. The planning process needed to include a margin of safety to account for this uncertainty, as well as building in opportunities for reevaluation as scientific knowledge developed.

Restructuring the Federal/State Relationship in Flood Control

USACE's relationship with local flood control entities in Southern Louisiana has been dysfunctional. Some of the issues relate to the fragmentation of the local entities, which the state has begun to address. However, the issues are broader.

Often, water planning activities involve not only multiple federal agencies, but also state and local governments. In the blunt words of one observer, "The first consequence is that flood control has no head Whatever the merits of this diffusion of authority, it does not produce coherent flood control." (Houck 2006, p. 14). One useful model may be what has been called "modularity" -- a concept which involves provisional and functional rearrangement of units in terms of alternative configurations of tools, structures and relationships. (Freeman and Farber 2005).

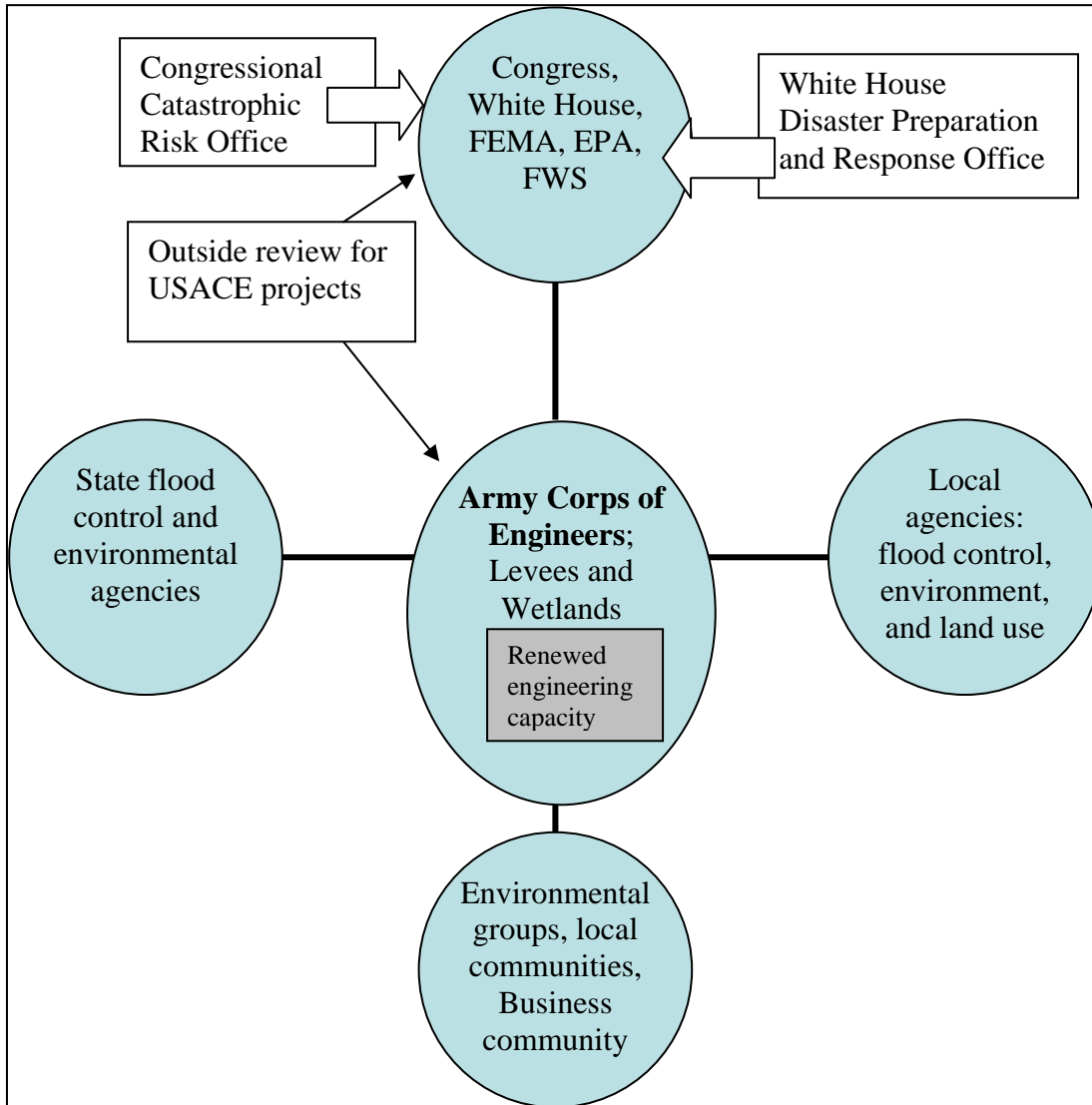
The Corps has traditionally viewed itself in insular terms. To be successful in the future, it must re-conceptualize itself as a pivotal part of a modular organizational structure, bringing together partnerships with other federal agencies, state and local government, and private stakeholders.

Some definite progress is being made on the state side in Louisiana. Under a proposed change in the Louisiana state constitution, which will be considered by voters in a September statewide election, establishes the Southeast Louisiana Flood Protection Authority - East and the Southeast Louisiana Flood Protection Authority - West, abolishing the existing levee boards in the region while maintaining the existing levee taxing districts. The Louisiana Coastal Protection and Restoration Authority, established in the November 2005 special session to oversee local levee boards and set state levee

priorities, will serve act as the local sponsor for flood control and coastal restoration projects in the new authorities.

Given the previously fragmented nature of Louisiana flood control efforts, this is a major step forward. But it is important to consider not only the state structure, but its interrelationships with various federal agencies and policymakers. Much remains to be done in terms of reconceptualizing these relationships.

One possible structure for flood control planning is shown in the following diagram:



Creating Effective Disaster Planning

Research on organizational learning finds that practices and routines in organizations develop incrementally through feedback from the organization's environment.

Organizations generally tend to be inert, adapting less than perfectly to and falling in and out of alignment with their environments (Nelson & Winter, 1982).

This stagnation is especially dangerous for organizations that deal with major emergencies such as floods, fires, and other natural and manmade disasters. Organizations that await major failures to adapt tend to enter crisis mode and find learning and response even more difficult (Staw, Sandelands, & Dutton, 1981; Turner, 1976). For example, following the demise of the space shuttle Challenger, NASA faced political pressures, inertia, and resource constraints that expedited some organizational changes but made other structural and cultural adjustments more difficult (McCurdy, 1994). Furthermore, in the absence of a significant environmental change or destabilizing event, lessons learned in organizations often tend to be forgotten or misapplied (de Holan & Phillips, 2004; March, Sproull, & Tamuz, 1991).

Even worse, because of the infrequency with which major disasters occur, trial and error organizational learning processes may lead organizational members to forget lessons from past disasters. Levitt and March (1988) argue that in the case of disaster preparedness, trial and error processes lead to “pernicious learning” – organizational leaders conclude that resources designated for disaster preparedness are left idle and should be applied elsewhere. Disaster preparation calls for a different form of learning in which organizations draw on not only their own experiences but also those of other organizations. Such network effects exist for a variety of learning processes (e.g., Argote, Beckman, & Epple, 1990; Baum & Ingram, 1998; Beckman & Haunschild, 2002).

Over the past few decades, scholars from many disciplines have advocated relational or systems approaches, as opposed to reductionist approaches that study particular events and entities in isolation (Miller, 1972; Wolf, 1980). Taking a relational approach will help us identify and examine learning processes as they affect and are influenced by organizations responding to major catastrophes. The issues we discuss may occur at several different levels in organizations – the interpersonal level, the subunit level, or the inter-organizational level.

Fortunately, we have learned a great deal about how to overcome these organizational barriers. What is needed is to instill “mindfulness” toward risks. We suggest three ways of doing so.

Making FEMA into an HRO

Some organizations cannot afford to fail. Accidents can be disastrous on nuclear submarines, aircraft carriers, air traffic control, and hospital emergency rooms. Successful organizations of these kinds have learned to attain high reliability. By studying these organizations, experts have learned the ingredients to creating a High Reliability Organization (HRO).

One of our goals must be to make FEMA (or any successor organization) into a High Reliability Organization, applying the lessons of the past generation of organizational research. We have some idea from these studies of how organizations can attain high

reliability. The big barrier is that the organization has to have the desire to attain this goal, either because of outside pressures, bold leadership, or both.

Creating a National Disaster Advisor in the White House

There is no one in the White House whose job is disaster response. Yet, federal disaster response requires action by many agencies – not just FEMA but also DOD, EPA, CDC, and others. White House coordination of these executive branch activities is crucial. Just as the White House has a National Security Advisor, it needs to have an official charged with national disaster oversight. This official would also be in charge of monitoring organizational problems in the line agencies in charge of disaster response. Moreover, a natural part of the official’s portfolio would be disaster prevention efforts, where the aim should be to avoid ever again being taken unawares by a “predictable surprise” like Katrina.

A new National Disaster Advisor should be appointed within the White House and given oversight of disaster preparation and response. This person should be a direct report to the President, like the National Security Advisor. In terms of combined loss of life, property damage, and economic disruption, Katrina was as serious a loss for the United States as 9/11. Both kinds of catastrophes are equally deserving of attention at the highest level.

Creating a Catastrophic Risk Office within Congress

An *integrated* approach to catastrophic risk is lacking. One lesson from Katrina is that disasters are not just engineering failures, they are social system failures. Societal infrastructures as well as physical ones can suffer collapse. Consequently, disaster prevention cannot be considered in isolation from disaster response, mechanisms for compensation and risk spreading, and reconstruction planning. All of these issues are tightly coupled, yet the linkages receive little attention.

Under the Constitution, Congress bears the primary responsibility for developing national policy and setting national priorities. It is Congress that authorizes and controls FEMA, the Army Corps, flood control projects, the flood insurance program, and other aspects of our nation’s response to catastrophic risks. Yet Congress has lacked the expertise needed to accomplish these tasks in a systematic way.

Congress should establish a Catastrophic Risk Office, akin to CBO, with the obligation of providing the best possible objective advice about disaster planning, prevention, and recovery.

Using GIS Technology to Overcome the “Fog of Disaster”

Catastrophic risks involve complex spatial interactions. For example, understanding what happened in New Orleans requires detailed information about the city’s complex flood control system, terrain, urban development, demographics, environmental hazards, and

infrastructure. But creation of the analytical tools to analyze spatial data can be labor intensive and very time consuming, and the various databases cannot be easily integrated or updated. Moreover, the raw data is not embedded in software that allows ready analysis.

When disaster strikes, decisionmakers find themselves starved for information. The information they need to know exists – somewhere – but they have no good way to access it quickly or make sense of it. Geographic Information Systems provide the answer. They also allow decisionmakers to model the effects of decisions made before, during, and after the crisis.

A decade of revolutionary advances in remote sensing and global positioning technologies, along with a significant increase in computing power, has provided us with very large and complex data rich environments. Current online access is often beset with varied system interfaces that force the end user to become an expert in order to navigate and extract data successfully. A solution to these impediments is an online geographic information library that serves geo-spatial data where problems associated with interoperability have been eliminated.

GIS servers can serve as a repository of GIS data and remote sensing imagery and a point of access (discovery, retrieval, and visualization) of internet-accessible GIS data processed for ease of use by CCRM researchers and other university clients. This seamless, real-time data sharing capability for geodata collections is a unique and increasingly important resource.

The federal government should develop deep and wide GIS capability for disasters. Systems must be established in advance for major metropolitan areas that could be struck by national disasters or major terrorist actions. These systems should integrate remote sensing with information about infrastructure vulnerabilities and site-specific risk assessments.

Conclusion

There are no cure-alls for potential disaster. Despite our best precautions, we will sometimes be caught unprepared, and our best precautions may not always be forthcoming. (As the saying goes, “against stupidity the gods themselves struggle in vain.”) But inherent imperfection is no excuse for the absence of best efforts. We do have a considerable body of data and theory, drawn from many disciplines, about catastrophic risks, their causes and statistical characteristics, and the techniques for addressing these issues. Katrina was not one of those bizarre events that was beyond human control, a true “act of God.” It was a “predictable surprise,” one we could have and should have planned for. Instead, we allowed the wetland buffers to disappear, the flood control system to stutter forward in a bureaucratic haze, and the relief effort to degenerate. If another Katrina happens, we will have no one to blame but ourselves.

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