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Floods, Famines, or Feasts: Too Much, Too Little, or Just Right

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The United States has a passionate love-hate relationship with water. Americans love to live beside rivers and lakes and use them for drinking water, washing, fishing, generating power, navigating, and recreation. They also love to be able to use water from rivers, lakes, and the ground beneath their property to irrigate their crops. When it's too dry, they pray for rain. But when it's too wet, they beg for sunshine, because as much as they love living as close to the water as they can get, people hate having their homes, workplaces, and crops inundated by floodwater even more. Besides prayer, what is the prudent person to do? When it comes to floods, it seems that there are only two choices. The first: move out of the floodplain. In the wake of the 1993 floods from the Mississippi and Missouri Rivers, some people did just that. The second option is far more common, however: build huge levees to keep the rivers between their banks and build dams to hold back the water and protect the floodplain from, well, flooding.

What is that same prudent person to do when it's too dry? Again, two choices come to mind. The first: conserve water. Use only so much as is absolutely needed for essential functions, like slaking thirst and fulfilling sanitary requirements. Although conservation mechanisms are being adopted in some areas of the country, once again, the second choice is by far the most prevalent: call on the engineers and financiers to boost water supplies by building dams, reservoirs, and canals and by digging ever-deeper groundwater wells.

There may be a third option, though, that addresses *both* problems. Could ecosystem restoration strategies come to the rescue and, by restoring the processes and functions of the nation's waterbodies, in turn foster a more sustainable relationship between water users and their water supplies? Although bureaucrats charged with managing water resources may scoff, plenty of law professors and ecologists dream about restoration as the cure for the evils of both flooding and drought. The lessons of history reveal the folly of doing anything *but* restoring a sustainable relationship with the nation's waters, while the lessons of ecology provide clues as to how to go about the restoration task. Environmental law and water law can serve as tools for achieving ecosystemwide restoration goals.

This literary journey begins with a bit of the history of the boom and bust cycles of droughts and floods that have played out during the course of our love-hate affair with water. The Great Plains serve as the focus for this exploration, but the journey will also turn to the Florida Everglades and the Grand Canyon of the Colorado River, where restoration projects are underway. Along the way, I'll examine the "usual suspects"—the typical technological and legal responses to drought and floods. Finally, I'll investigate ecosystem restoration as a strategy for a more sustainable relationship with water in all of its facets, through thick and thin, flood, famine, and feast.

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Navigating Hunger and High Water in Search of a Water-Borne Manifest Destiny

In 1803, President Thomas Jefferson sent Meriwether Lewis and William Clark on their epic expedition in hopes of discovering an all-water route to the Pacific Northwest. Jefferson's dream was nothing less than securing the nation's Manifest Destiny—"an integrated nation that stretched from sea to sea." Donald Pisani, Water and American Government: The Reclamation Bureau, National Water Policy, and the West, 1902–1935, 273 (2002).

Early cartographers depicted the vast expanse of land west of the Mississippi River as "The Great American Desert," and subsequent explorers continued to call it "a desolate waste of uninhabited solitude . . . wholly uninhabitable by a people depending on agriculture for their subsistence." Wallace Stegner, Beyond the Hundredth Meridian: John Wesley Powell and the Second Opening of the West 399 (1992). Yet, it was a region uniquely suited to its occupants. On the Great Plains, bison, elk, and antelope grazed on native prairie grasses that were well adapted to the climatic extremes of drought, wind, fire, floods, and freezing weather. "As long as the weave of grass was stitched to the land, the prairie would flourish in dry years and wet. The grass could look brown and dead, but beneath the surface, the roots held the soil in place; it was alive and dormant." Timothy Egan, The Worst Hard Time: The Untold Story of Those Who Survived the Great American Dust Bowl 112 (2006).

The prairie was destined for something else, however. The nation's dream of Manifest Destiny entailed consumption of natural resources on an unprecedented scale. By the late 1800s, the U.S. government had virtually eradicated the buffalo and had encouraged homesteaders to plow under the native grasses and raise cattle and to grow wheat and corn. Hardy Campbell, author of *Campbell's 1907 Soil Manual*, fueled the homesteaders' dreams by arguing that "rain follows the plow." H. W. Campbell, Campbell's 1907 Soil Culture Manual: A Complete Guide to Scientific Agriculture as Adapted to the

Semi-Arid Regions (1907). He believed that the commotion of plowing, along with the railroads' use of steam engines, would perturb the atmosphere and bring rain.

Rain did not follow the plow, and thousands of homesteaders were driven off the Plains by recurring droughts and harsh winters in the 1870s and 1890s. Down but not out, settlers returned to the area with their dreams and their plows in the early 1900s, and, after World War I, they had grounds for optimism. Prices were high and there was just enough rain over the Plains. The federal government urged farmers to break historic records for crop yields, and they did.

During the "Roaring Twenties," Americans went on a spending spree purchasing automobiles, appliances, and other goods, and farmers invested heavily in planting more grain. But increased production brought a glut on the global markets. Prices plummeted. The stock market crashed on Black Tuesday, October 29, 1929, and on its heels a devastating drought hit the Great Plains. Residents experienced a new kind of weather—a black duster. Formed of loose, dry top soil picked up by incessant winds, the dusters ruined fields, choked livestock, and caused a deadly respiratory disease in humans, much like brown lung experienced by textile workers. Before the dust settled—much of it hundreds of miles away from its place of origin—over one hundred million acres of cropland had lost its topsoil.

Several decades earlier, John Wesley Powell had argued that, given the arid climate, ordinary farming and ranching practices would not work in the West. *Public Lands Council v. Babbitt*, 529 U.S. 728, 732 (2000) (citing Report on the Lands of the Arid Region of the United States 28 (1878)). President Theodore Roosevelt, himself a cattle rancher with holdings in the Dakotas, renewed Powell's recommendations to regulate the public grasslands. But it took a couple more decades, plus the Dust Bowl, to overcome westerners' opposition. The once-fertile topsoils of the Great Plains blew east to Washington, D.C., literally whirling around the Capitol as Congress debated the merits of grazing and farming reforms. The dusters eclipsed the sun and turned the air a dark copper color, making "the most impressive lobbyist" ever to come to the Capitol. *Public Lands Council*, 529 U.S. at 733 (citing 79 Cong. Rec. 6013 (1935)). The Taylor Grazing Act of 1934 established grazing districts for millions of acres of public land and placed them under regulation by a new Grazing Service, and later the Bureau of Land Management. 43 U.S.C. §§ 315–315o-1.

When it came to reforming cropping practices, Congress turned to Hugh Bennett, a farm boy from North Carolina who adhered to Aldo Leopold's view of soil as a living thing, not just a conduit for producing commodities. Bennett recognized that intensive plowing, far from bringing rain, had in fact upset the land's delicate relationship with water, depleted the topsoil, and spread invasive weeds. Egan, *supra*, at 134, 270.

Congress declared soil erosion "a national menace," and passed the Soil Conservation Act of 1935, Pub. L. No. 74-46, 49 Stat. 163 (codified as amended at 16 U.S.C. §§ 590a–590q-3 (2000)), and Bennett became the first director of the brand new Soil Conservation Service (SCS). The SCS and related programs incentivized conservation measures such as planting windbreaks, seeding grass, rotating crops, and constructing terraces. These measures proved invaluable in preventing the topsoil from blowing away again in subsequent droughts.

Droughts are still a regular occurrence on the Great Plains, but since the 1950s farmers have been far less worried about them. After World War II, cheap rural electricity, powerful centrifugal pumps, and center pivot irrigation systems became available, fostering increased reliance on groundwater to irrigate crops. These new technologies wrought another profound change to the landscape and water resources of the Great Plains.

The Ogallala (High Plains) Aquifer, underlying Nebraska, Kansas, Oklahoma, Texas, New Mexico, and small parts of Wyoming, Colorado, and South Dakota, has become especially important.

> If you snack on popcorn or peanuts, you are probably eating Ogallala water; if you dress in cotton clothing, you are probably wearing it . . . The fourteen million acres of crops spread across its flat surface account for at least one-fifth of the total annual U.S. agricultural harvest. . . . If the aquifer went dry, more than [$]20 billion worth of food and fiber would disappear immediately from the world's markets.

William Ashworth, Ogallala Blue: Water and Life on the High Plains 10 (2006). The southernmost portion of the aquifer is, in fact, going dry. Groundwater levels have declined more than 150 feet in some areas, making it impossible or at least impractical to extract more water.

The desire to minimize reliance on Middle East oil and to minimize greenhouse gas emissions by promoting corn-based ethanol is adding fuel to the metaphorical prairie fire of diminishing aquifers. A quarter of the total U.S. corn crop in 2007 was used for ethanol. Total corn production rose to a record 13 billion bushels, up from 10 billion bushels annually in 2000 to 2006, and, going back further, from only 2 billion annually in the 1930s. USDA Economic Research Service, Feed Grains Database: Yearbook Tables, www.ers.usda.gov/data/feedgrains/StandardReports/YBtable1.htm (last visited July 14, 2009).

Ethanol production has significant ramifications for water supplies. In arid areas of the Great Plains and the West, corn, a thirsty crop, can survive only if it is irrigated. Irrigation typically relies on groundwater and, over time, depletes or "mines" underground aquifers, many of which are closely connected to surface water bodies. State laws governing groundwater allocation and use vary significantly, but most have one thing in common—they fail to address groundwater mining and its effects on surface water flows.

Until well into the twentieth century, courts stayed out of disputes over groundwater, which was deemed too "secret, occult and concealed" to be subject to regulation. *Frazier v. Brown*, 12 Ohio St. 294, 300 (1861), overruled by *Cline v. Am. Aggregates Corp.*, 474 N.E.2d 324 (Ohio 1984). This view rationalized the "rule of capture," which awards landowners with rights to water percolating beneath their land's surface when they capture it by pumping. As a result, landowners could pump to their hearts' content, despite adverse impacts to their neighbors and to streamflows.

Today, most states have abrogated this rule in favor of reasonable use rules, which allow groundwater pumping for almost any nonwasteful purpose but only on the overlying land itself. Reasonable use laws may be a step forward from the rule of capture, but they address groundwater mining crudely, at best. In many areas, groundwater mining has caused severe land subsidence, saltwater incursion, and bone-dry seeps, springs, and streams. *See* ROBERT GLENNON, WATER FOLLIES: GROUNDWATER PUMPING AND THE FATE OF AMERICA'S FRESH WATERS (2002). Interference with neighboring wells and with surface water appropriations has become common, generating protracted litigation but few sustainable solutions. *See, e.g., Spear T Ranch v. Knaub*, 269 Neb. 177, 691 N.W.2d 116 (2005). Even with modern geographic information systems, groundwater remains a subject of "misinformation, misunderstanding, and mysticism," all of which add up to mismanagement. John D. Leshy, *The Federal Role in Managing the Nation's Groundwater*, 11 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 1 (2004).

By altering the landscape and its ecological processes through engineered devices and structures, we're fighting a losing battle with ever-higher stakes.

Just as we've relied on engineered solutions, such as center pivots and powerful pumps, to extract groundwater and to divert surface water supplies to address the lack of water, we rely on engineering "fixes" to address the problem of having too much water at any given time. During the early twentieth century—the "Big Dam Building Era"—rivers all across the nation were channelized, rip-rapped, leveed, and dammed in the name of flood control. As with soil erosion, Congress declared an all-out war on flooding as a "national menace." On the lower Mississippi, massive levees were constructed to keep the river in its banks. Upstream, on the Missouri, dams and reservoirs became the preferred option for protecting population centers and farms while at the same time providing navigation benefits and water supplies.

On the Missouri River, Congress authorized five huge new mainstem dams in the upper basin, primarily for flood control and navigation, in the Flood Control Act of 1944. Pub. L. No. 78-534 ch. 665, 58 Stat. 887 (codified in various provisions of Titles 16, 33, and 43 of the U.S. Code). *See ETSI Pipeline Project v. Missouri*, 484 U.S. 495, 502 (1988). In the lower basin, Congress authorized an assortment of structural devices, such as revetments, riprap, and wing dikes, to maintain the navigation channel and armor the river's banks.

Since the system's completion in 1967, the hope of lucrative river navigation has failed to materialize. The projected annual use of the Missouri was 12 million tons of cargo; actual use hovers around 1.5 million tons. Today, only a miniscule amount of the grain exported from riparian states is carried on the river, and railroads have proven to be much more economical. National Research Council Water Science and Technology Board, The Missouri River Ecosystem: Exploring the Prospects for Recovery 78 (2002) (NRC Report).

On the other hand, the dams have prevented an estimated $400 million in annual flood damage. NRC Report, *supra*, at 78–83. The system proved woefully inadequate to the task, however, in 1993, when the Midwest was hit with an entire year's worth of precipitation in less than three months. Forty of 229 federal levees and 1,043 of 1,347 nonfederal levees were overtopped or breached. In Missouri, floodwaters reached the steps of the St. Louis Arch and the Spirit of St. Louis Airport was submerged. Widespread evacuations were mandated. By late summer, 17,000 square miles had flooded, breaking records for both intensity and duration all over Missouri, Minnesota, Iowa, and Illinois.

A blue-ribbon interagency committee reviewed the 1993 floods and recommended a shift in floodplain management away from dams, levees, and other structural devices to nonstructural approaches, such as wetland acquisition and restoration. GERALD GALLOWAY ET AL., INTERAGENCY FLOODPLAIN MGMT. REVIEW COMM, SHARING THE CHALLENGE: FLOODPLAIN MANAGEMENT INTO THE 21ST CENTURY viii–ix (1994). Thousands of acres of wetlands have since been enrolled in conservation programs or purchased outright by federal and state agencies and nonprofit organizations from willing sellers throughout the basin.

Even so, development in the floodplain has continued apace. For example, in Chesterfield, Missouri, on the Missouri River just above its confluence with the Mississippi at St. Louis, a developer took advantage of the state's tax-increment financing for "blighted" areas to build the nation's largest strip mall on land that was submerged under fifteen feet of water in 1993. Christine Klein and Sandra Zellmer, *Mississippi River Stories: Lessons from a Century of Unnatural Disasters*, 60 S.M.U. L. REV. 1471, 1495 (2007). Faith in reservoirs, levees, and federally subsidized flood insurance and disaster relief (topics beyond the scope of this article) appears to outweigh experience.

Even if Missouri River navigation and flood control haven't turned out to be what the nation had hoped, two other benefits of the upstream dams and reservoirs have become readily apparent. Millions of dollars from recreational use have been generated by the impoundment of vast quantities of water in the upper basin reservoirs, which support a prolific walleye fishery. In the lower basin, steady flows provide domestic water supplies for 3 million people, as well as cooling and pollution dilution for numerous coal-fired power plants. NRC Report, *supra*, at 74–76. These interests depend on keeping water instream on both ends of the basin—an incredibly difficult task, made all the more challenging when the ecological needs of endemic species are considered. Three species, in particular, have been severely affected by the alteration of the river's flows. By 2003, the piping plover population on the Missouri River consisted of only about 2,000 birds, while the interior least tern population hovered around 7,000. The pallid sturgeon's plight is even grimmer. If artificial propagation with hatchery stocks were discontinued, the species would be extirpated from the wild by 2018.

When the U.S. Army Corps of Engineers (the Corps) began revising its master manual for Missouri River operations, it consulted with the U.S. Fish and Wildlife Service (FWS), which issued a finding of jeopardy under the Endangered Species Act (ESA)—if status quo operations continued, the listed species would face extinction. The National Research Council (NRC), an arm of the National Academy of Sciences, agreed with the FWS regarding the adverse effects of current operations on native species. It concluded that restoration of a more natural hydrograph was imperative and recommended comprehensive legislation to compel ecosystem restoration through adaptive management strategies. NRC Report, *supra*, at viii, 1–3.

In Search of a Water Management Approach That's "Just Right"

The historical pattern of action and reaction to droughts and flooding through diverting and pumping water and damming and diking rivers has wrought significant changes on water bodies throughout the nation. Aquifers are depleted, development continues apace in floodplains and wetlands, flooding still occurs on a colossal scale with flood damages to human communities steadily increasing, and species are being obliterated. By altering the landscape and its ecological processes through engineered devices and structures, we're fighting a losing battle with ever-higher stakes in terms of economic and environmental costs. It is time to take a step away from the engineered solutions of the past, which have created as many problems as they have solved.

Water management strategies, like natural resource management strategies more generally, have evolved over the years. Exploitation-dominated approaches prevailed throughout the nineteenth and much of the twentieth centuries, as managers strived to attain maximum yields of resource outputs. Every drop of water was to be diverted and used or it was deemed "wasted." Beginning in the 1960s, resource managers sought to mitigate the effects of these policies by adopting sustained yield principles, which still strived for optimum resource outputs but were tempered with a requirement that outputs be sustained over the long term. Flood control policies remained largely the same as they had in previous years, but the federal government became more involved in disaster relief and flood insurance to mitigate harm to floodplain residents. In the 1970s, resource managers began to emphasize pollution prevention, the preservation of wildlife and instream flows, and recreational opportunities. Now, at the turn of the twenty-first century, ecosystem restoration is fast becoming a dominant natural resources management strategy. Sandra Zellmer and Lance Gunderson, *Why Resilience May Not Always be a Good Thing: Lessons in Ecosystem Restoration*, 87 NEB. L. REV. 893 (2009).

Ecosystem restoration means "returning an ecosystem to a close approximation of its condition prior to disturbance." NRC, RESTORATION OF AQUATIC ECOSYSTEMS: SCIENCE, TECHNOLOGY AND PUBLIC POLICY 2 (1992). In a human-altered environment, how close can that approximation be? It may be impractical to insist on restoration to the predisturbance state, but we can seek a condition that resembles a more natural, resilient state where both humans and nonhuman life can thrive. The Everglades restoration plan, for example, seeks to recover the ecosystem "so that it once again achieves and sustains those essential hydrological and biological characteristics that defined the undisturbed South Florida ecosystem." 33 C.F.R. § 385.3 (2008). Resilience, in turn, is an expression of those essential characteristics that maintain an ecosystem's ability "to persist, buffer, and adapt to recurrent shocks without fundamentally changing, often unpredictably, into highly altered systems." Terence P. Hughes et al., *Adaptive Management of the Great Barrier Reef and the Grand Canyon World Heritage Areas*, 36 AMBIO 586 (2007).

Good intentions aside, recent restoration efforts in the Everglades, the Grand Canyon, the Missouri, and other river basins throughout the country are being driven, and in some cases constrained, by first- and second-generation environmental and water laws. In the Everglades and on the Missouri, the key drivers are the various Flood Control Acts of the 1930s and 1940s, plus two environmental laws of 1970s vintage, the Clean Water Act (CWA) and the ESA. In the Grand Canyon, the decades-old Law of the Colorado River governs water use and allocation, while the ESA regulates flow to protect listed species.

Studies of ongoing restoration efforts on the Everglades and in the Grand Canyon show that success is not possible if the emphasis on engineered solutions continues, and if environmental and water law is not carefully calibrated with the science of ecology to foster experimentation, learning, and adaptation in management strategies. The $8 billion Comprehensive Everglades Restoration Plan of 2000 is an expensive example that strives to undo the adverse effects of dams and other forms of human engineering for flood control and water supply by employing ever-more human engineering.

Throughout the past century, the State of Florida and the Corps constructed an extensive network of man-made canals, levees, impoundments, and other water-control structures to drain and divert billions of gallons of water from the Everglades out to the ocean. Meanwhile, the burgeoning cities began to rely heavily on groundwater pumping from the Florida and Biscayne Aquifers to supply their needs. Today, the Biscayne Aquifer is the primary source of water for Broward and Dade Counties as well as a portion of Palm Beach County. Excessive pumping has lowered the water table and, in some areas, has depleted stream flows and caused the land's surface to subside and crater into gaping sinkholes.

As surface and groundwater sources receded, so too did the habitat of wading birds, fish, and dozens of wildlife species. According to a 1999 Corps of Engineers study, the Everglades has lost 70 percent of its freshwater sheet flows, which for centuries had maintained the ecological functioning of this unique area. As a result, at least sixty-eight of the Everglades' native species are endangered, while exotic species have invaded and colonized much of the Everglades. C&SF Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Impact Statement 3-1 (1999), www.evergladesplan.org/pub/restudy_eis.aspx#mainreport. Meanwhile, the loss of freshwater flows allowed saltwater to intrude farther into the marshes, and pollution, especially phosphorus, further degraded what little habitat remained. Florida DEP, Brief History of the Everglades, www.dep.state.fl.us/evergladesforever/about/default.htm.

Rather than relying on natural, pre-alteration processes to mediate these adverse effects, the Everglades Restoration Plan entails nothing less than re-plumbing southern Florida by capturing one trillion gallons of rainwater, storing it in reservoirs and injection wells, and then pumping and distributing it to farms, cities, and Everglades National Park. Although the plan calls for the removal of more than 200 miles of levees and canals, it also envisions the construction of dozens of newly engineered devices—levees, canals, and pumps—along with the creation of thousands of acres of water-storage and treatment areas, all in hopes of "getting the water right." Zellmer and Gunderson, *supra*, at 918.

The Restoration Plan devotes too much attention to the use of heroic engineering techniques to expand water supplies and ensure flood protection, and it places too much emphasis on maintaining stakeholders' economic interests. As a result, according to a 2007 Government Accountability Office report, implementation of restoration projects has left much to be desired. *Id.* at 921. The Restoration Plan's cost is now estimated at $10.9 billion, and completion is not anticipated until the 2030s or 2040s. Yet two facets of the plan offer hope for the future. First, Congress authorized a $100 million Adaptive Assessment and Monitoring Program. This program goes hand in hand with a requirement that new information from changed or unforeseen circumstances or from new scientific findings be assimilated during the plan's implementation through programmatic regulations that must be reviewed every five years. In addition, an independent scientific review panel is required to assess the plan's progress and report its findings to Congress every other year. Pub. L. No. 106-541, § 601(b)(2)(C)(xi), 114 Stat. 2572, 2681 (2000).

Meanwhile, the State of Florida has taken some important steps that promote ecosystem restoration through water-law reforms. The Florida Water Resources Act requires permits for all consumptive uses of "water," defined as "any and all water on or beneath the surface of the ground or in the atmosphere . . . ." Fla. Stat. Ann. § 373.019(20). Notable provisions of the Act, from a restoration standpoint, integrate surface and groundwater supplies (including flood control), as well as water-quality and water-quantity concerns, and provide for environmental protection. Fla. Stat. Ann. §§ 373.026, 373.069. Perhaps most importantly, Florida law allows managers to reserve water from use by permit applicants in order to protect fish and wildlife species, Fla. Stat. Ann. §§ 373.223(4), 373.470(3)(c), and requires minimum flows and levels to be established in order to prevent harm to water resources or area ecology. Fla. Stat. Ann. § 373.042(1)(a). Consumptive use permits cannot be issued if they would be inconsistent with minimum flows or levels. To date, however, these provisions have been "under-utilized." Christine A. Klein, Mary Jane Angelo, and Richard Hamann, *Modernizing Water Law: The Example of Florida*, 61 Fl. L. Rev. 1, 43 (2009). Although more than 250 minimum flows and levels have been set throughout the state, there are still thousands of water bodies that have none. *Id.*

Restoration efforts on the Grand Canyon have been more successful for at least two reasons. First, the federal government, through the Secretary of the Interior, has taken a strong leadership role, which seems to have produced a greater degree of trust and mutual respect between and among the major stakeholders and the scientists. Second, the restoration plan does not rely on newly engineered structures or devices to move water around, but rather it experiments with simulated natural flows by adapting the operations of existing dams.

After Glen Canyon Dam became operational in 1962, the ecosystem changed dramatically. Historically, the river was characterized by extreme floods, large sediment loads that colored the water red, and dramatic seasonal temperature fluctuations. Since 1962, the river below the dam has relatively stable flows, clear water, and a near-constant temperature. The result: the loss of seven species of native fish, the endangerment of four others, and a dramatic reduction in habitat diversity. Zellmer and Gunderson, *supra*, at 924.

Thirty years after the completion of the dam, Congress passed the Grand Canyon Protection Act of 1992, requiring the Secretary of the Interior to operate the dam "in such a manner as to protect, mitigate adverse impacts to, and improve the values" of Grand Canyon National Park. Pub. L. No. 102-575, §§ 1801–09, 106 Stat. 4600, 4669–73. To accomplish the goals of the Act, the Secretary of the Interior established the Glen Canyon Dam Adaptive Management Program (AMP) to be implemented by a federal advisory committee comprised of stakeholders and scientific advisors. The AMP emphasizes "research protocols that seek repeated monitoring and, if necessary, adjustment of regulatory restrictions to account for new information or changed circumstances that arise during implementation." Zellmer and Gunderson, *supra*, at 927. Experimental releases from Glen Canyon Dam have been used to test current understanding of the system's water, sediment, and nutrient dynamics. The experiments surprised scientists by disproving their previous hunch that sufficient sediments remained in the postalteration river to replenish sandbar habitats throughout the canyon. Consequently, experimental flows are being modified in order to reestablish sediment transport from other upstream sources. In short, people are willing to learn from the experiments and use them to transform the management of the system.

Experience with the Everglades and the Grand Canyon programs shows that the restoration of ecosystems altered in the name of water supply or flood control will require the development of bold, broad-scale, long-ranging, integrated solutions to restore degraded conditions. This is best done by restoring natural functions and processes to the greatest extent possible within the human-altered system.

It is not altogether clear whether existing federal environmental laws help or hinder the restoration cause. The CWA, in a nutshell, prohibits unregulated discharges of pollutants, including dredged or fill materials, unless permits are obtained. 33 U.S.C. §§ 1331(a), 1344(a). It addresses runoff from nonpoint source polluters, such as agriculture, only minimally, and it does not address groundwater depletion or pollution at all; rather, these issues are left to the state and local levels of government, which vary tremendously in their approaches. The ESA, for its part, prevents any person from taking federally listed species and prevents federal agencies from causing jeopardy to the species. 16 U.S.C. §§ 1536, 1538. Habitat conservation plans (HCPs) have been adopted under the ESA in hopes of mitigating the effects of harmful activities on Everglades and Grand Canyon species, but compliance monitoring is typically "deficient, if not entirely absent, and subsequent adaptation of HCPs to integrate new information or changed circumstances acquired during implementation is even rarer." Alejandro E. Camacho, *Can Regulation Evolve? Lessons from a Study in Maladaptive Management*, 55 UCLA L. REV. 293, 297 (2007). In short, the ESA is reactive— stopping already imperiled species from slipping into extinction—rather than proactive. Proactive species protection would entail a more holistic, ecosystemwide approach to maintain and enhance biological diversity by protecting both population viability and habitat viability of interrelated communities of species.

Neither the CWA nor the ESA requires adaptive management, which ecologists agree is a key strategy for resolving the uncertainties of restoration science and ecological functioning in heavily altered, highly complex systems, such as the Everglades, the Grand Canyon, or the waterbodies of the Great Plains. Although several of the resource management agencies, including the Corps and the FWS, have begun to adopt adaptive techniques through their regulations and guidelines, adaptive management is not explicitly required by *any* of the major federal environmental laws. Experiences with the Everglades and the Grand Canyon indicate that it should be compelled by statute and that funding for monitoring and adaptation should be assured throughout project implementation.

I suspect that broad-sweeping, generally applicable national legislation, such as an Ecosystem Restoration Act, will be necessary to replace the existing maximum-yield mindset of natural resources management with adaptive, ecosystem-based strategies. This article is not the appropriate forum for detailed prescriptions, but a few "big picture" concepts can be identified for moderating our love-hate affair with water in a way that favors river-basin integrity. Rather than striving to recover discrete resources, like water supplies, to prescribed levels, and rather than freezing ecological conditions at some predetermined, socially desirable state, restoration plans should focus on restoring natural hydrological and biological processes by which ecosystems maintain resilience. The virtues of this approach are two-fold. First, restoring natural processes requires less ongoing, human intervention over the long run. At least equally importantly, restoring natural processes allows ecosystems to evolve over time, just as they did before artificial disturbances. With a bit of evolution itself, environmental law can serve as a tool for achieving ecosystem restoration goals by incorporating adaptive management principles, with ecological and social resilience as the overarching goal.