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New Orleans, the Chesapeake, and the Future of Environmental Assessment: Overcoming the Natural Resources Law of Unintended Consequences

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ARTICLES

NEW ORLEANS, THE CHESAPEAKE, AND THE FUTURE OF ENVIRONMENTAL ASSESSMENT: OVERCOMING THE NATURAL RESOURCES LAW OF UNINTENDED CONSEQUENCES

Erin Ryan *

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I. INTRODUCTION: THE NATURAL RESOURCES LAW OF UNINTENDED CONSEQUENCES

This is a cautionary tale of two wetlands, each providing new insight into the old problem at the heart of natural resources law, each offering new testimony for the old rule of unintended consequences. It is the story of two vast regions of coastal and intertidal marsh that have been dissolving into salty waters despite the most well-intended natural resource management policies. The plight of those who depend on these wetlands—and the frustration of those who accidentally hastened their demise—highlights the importance of developing more sensitive models of environmental assessment to match the increasing efficacy of our technological power to alter the environment, even inadvertently.

This article tells the stories of the disappearing wetlands ringing the Gulf Coast of Louisiana and the Chesapeake Bay of Virginia and Maryland, which are vanishing under different circumstances but bear the same message for environmental policy makers: more sophisticated natural resource planning is required to avoid the unanticipated consequences that can cause even well-intended policies to backfire. The stories suggest that a model of environmental assessment that better tracks the complex network characteristics of regional ecosystems would yield better long-term results, and this article proposes a network-based model that expands the lateral, temporal, and causal analysis of conventional environmental review.

Although the Louisiana and Chesapeake wetlands are disappearing under different circumstances, we will miss them for

many of the same reasons. As do all wetlands, the Louisiana and Chesapeake wetlands function as the mushy margin between land and water—the buffer zone that protects what is best about either side from undue interference by the other. Like the spongy doormat strategically placed at your threshold, tidal wetlands absorb the stream of overland pollutants washed by stormwater from our streets, yards, factories, and farms toward the sea, mitigating the marine-fouling effects of fertilizer, pesticides, motor oil, asphalt sealants, and cleaning solvents that threaten water quality, commercial fisheries, and marine ecosystems on the other side of the wetland.¹ But the spongy doormat is amazingly reversible: the same wetland serves to mitigate the undesirable movement of sea onto land, absorbing the effects of tidal flooding and storm surge that otherwise threaten the integrity of coastal development and habitat.²

Increasing coastal development makes us more vulnerable on either side of this threshold; more development means more land-based marine pollution to intercept and more vulnerable investment to protect against marine incursion. And yet at least half of all wetlands along the East Coast have already been lost to development since western settlement,³ and with them the many important ecosystem services that wetlands provide, including pollutant filtration, flood control, and marine nursery habitat.⁴

Since the late 1980s, we have heralded a national wetlands policy of “no net loss,” pledging to forestall further degradation of this critical wetland margin.⁵ And yet the Louisiana Gulf Coast and Chesapeake wetlands—two of the most admired and commercially important regional wetlands in the nation—continue to

1. See E.P.A., Wetlands Functions and Values Module, <http://www.epa.gov/waterstrain/wetlands/module05.htm> (last visited Apr. 5, 2006).

2. See Robert Viguerie, *Coastal Erosion: Crisis in Louisiana's Wetlands*, 51 LA. B.J. 85, 86 (2003).

3. Thomas E. Dahl, *Wetlands: Losses in the United States 1780's to 1980's* (U.S. Dep't of the Interior, Fish and Wildlife Service, 1990), available at <http://www.npwrc.usgs.gov/resource/othrdata/wetloss/wetloss.htm>; see also JAMES RASBAND ET AL., NATURAL RESOURCES LAW AND POLICY 821 (2004) (“Since European settlement, the continental United States has lost roughly half of its wetlands through drainage, conversion, and erosion.”). In many states, “urbanization is responsible for over 90 percent of coastal wetland losses.” DAVID SALVESON, WETLANDS: MITIGATING AND REGULATING DEVELOPMENT IMPACTS 21 (2d ed. 1994).

4. WILLIAM MURRAY TABB & LINDA A. MALONE, ENVIRONMENTAL LAW: CASES AND MATERIALS 642 (2d ed. 1997).

5. RASBAND ET AL., *supra* note 3, at 821.

disappear. The waning coastal wetlands of southern Louisiana became national news when the storm surges of Hurricanes Katrina and Rita catastrophically flooded the City of New Orleans. Meanwhile, the fragmented estuarine wetlands of the Chesapeake are all that stand in the way of further degradation of the most commercially and environmentally important estuary in the country,⁶ made famous by the growing “dead zone” that began drawing serious concern in the 1950s.⁷

Although separate stories with distinct histories, the tales of the lost Gulf Coast and Chesapeake Bay wetlands unite to demonstrate the frustrating quandary at the center of modern natural resource management. Neither loss represents the result of laissez-faire resource exploitation; rather, each follows a lengthy era of well-intended resource management strategy. Louisiana’s losses follow three hundred years of natural resource engineering to accomplish effective flood control along the Mississippi River,⁸ while the Chesapeake losses follow the most meticulously forward-thinking and scientific program of wetlands-protective natural resource planning of its time. And yet, New Orleans suffered a catastrophic flood, and Chesapeake wetlands continue to disappear. How could this happen?

Call it the “Natural Resources Law of Unintended Consequences.” Louisiana’s pioneering natural resource managers tried to prevent flooding by channelizing the Mississippi River, but interfering with the natural cycle of sediment deposition in the floodplain starved the wetlands that would have mitigated the hurricane storm surge that drowned New Orleans after Hurricanes Katrina and Rita.⁹ Having learned the lesson of wetlands’ role within an ecosystem, Virginia resource managers attempted to protect intertidal wetlands by establishing a development-free

6. See HOWARD R. ERNST, CHESAPEAKE BAY BLUES: SCIENCE, POLITICS, AND THE STRUGGLE TO SAVE THE BAY 10 (2003) (“The Chesapeake Bay is the largest of the nation’s 850 estuaries.”).

7. The Chesapeake Bay Foundation, The Chesapeake Bay’s Dead Zone, http://www.cbf.org/site/PageServer?pagename=resources_facts_deadzone#cause (last visited Apr. 5, 2006) (“Over the last four decades, the volume of hypoxic and anoxic water in the Chesapeake Bay has more than tripled.”).

8. Beginning in the nineteenth century, navigation became as important a purpose of Louisiana’s levee system as flood control. See Oliver A. Houck, *Land Loss in Coastal Louisiana: Causes, Consequences, and Remedies*, 58 TUL. L. REV. 3, 21 (1983).

9. See Cornelia Dean & Andrew C. Revkin, *Hurricane Katrina: Geography; After Centuries of ‘Controlling’ Land, Gulf Residents Learn Who’s Really the Boss*, N.Y. TIMES, Aug. 30, 2005, at A14.

jurisdictional boundary. But when landowners then built all the way to the legal side of the line, they inadvertently doomed the protected wetlands by disconnecting them from the natural shoreline systems that sustain them during such periods of sea-level rise as we are currently experiencing.¹⁰ In each case, natural resource management accomplished the exact *opposite* of what policymakers had hoped for.

Of course, the protagonists in these stories may deserve our sympathy. When Louisianans first began channelizing the Mississippi, they may not have understood the process by which it would damage coastal wetlands, nor the significance of the loss.¹¹ They fell prey to the classic fallacy of single-issue natural resource management, by which early natural resource managers mistakenly believed that they could alter one feature in an ecosystem without worrying about the effects on other features within the system. Hundreds of years later, the Virginia Department of Natural Resources formulated a rigorous management strategy expressly based on the relationship between interdependent features in the Chesapeake Bay ecosystem. Applying the best-available science, they calculated jurisdictional boundaries of the tidal wetlands necessary to protect water quality in the most life-productive regions of the Bay, but, still in the early years of modern natural resource planning,¹² they did not consider how the policy would fare over long periods of time—and unfortunately, it did not fare well. Situated centuries apart, the two stories nevertheless show that the learning curve in natural resource management remains exquisitely painful.

Hindsight thus helps us understand *how* such unintended consequences came to pass, but the more important question is whether it can help us avoid like results in the future. And indeed, hindsight indicates that overcoming the Natural Resources Law of Unintended Consequences is possible, though it requires

10. See James G. Titus, *Does the U.S. Government Realize that the Sea Is Rising? How to Restructure Federal Programs So That Wetlands and Beaches Survive*, 30 GOLDEN GATE U. L. REV. 717, 718–19 (2000).

11. *But see* Houck, *supra* note 8, at 10 (documenting that these principles were established at least by the late 1970s and early 1980s). The decision by later natural resource managers, primarily the U.S. Army Corps of Engineers, not to change course in light of this understanding deserves less sympathy.

12. RASBAND ET AL., *supra* note 3, at 285 (“Other than the occasional consideration given to mineral-bearing lands, until well into the nineteenth century little thought was given to managing land with reference to the resources on that land.”).

more sophisticated natural resource planning tools. Each of our two cautionary tales show that wetland losses were incurred not for lack of planning, but for not planning *systemically enough*.

Natural resource management inevitably proceeds from a state of disquieting uncertainty; we never have all the science, all the data, or all the information we need to make vexing management decisions about such complex adaptive systems as regional ecosystems. Complex adaptive systems—found not only in nature but also in economics, organizational behavior, developmental learning, game theory, and neuroscience—are characterized by interaction between components within a unified system, or network.¹³ Complexity theorists suggest that complex adaptive systems function best when connectivity among the multiple components is fostered, and changes are effectively diffused across the self-correcting features of the network.¹⁴ Management strategies that anticipate the interconnectivity between even remote network components enable the network to function as an integrated whole.¹⁵

However, isolating cause and effect can be challenging when the connectivity between network components enables changes to reverberate back and forth within an ecosystem (for example, when flood control works contain a river within its banks, but lead to the depletion of coastal wetlands that would mitigate flooding, further stressing water levels at the river's terminus). But the lesson is not that natural resource planning is a hopeless endeavor dooming us to failure no matter how well-intended. The lesson is to better align assessment techniques with the model of network connectivity demanded by complex adaptive systems, and to preserve management flexibility as much as possible so that we can update approaches to adjust for new information.¹⁶ Respecting the integrated network of ecosystem components, en-

13. See MURRAY GELL-MANN, *THE QUARK AND JAGUAR: ADVENTURES IN THE SIMPLE AND COMPLEX* 16–21 (1994) (discussing the characteristics of complex adaptive systems). See generally M. MITCHELL WALDROP, *COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS* (1992) (describing the science of complexity theory and related research by the Santa Fe Institute).

14. See John R. Nolon, *Champions of Change: Reinventing Democracy Through Land Law Reform*, 30 HARV. ENVTL. L. REV. 1, 11–16 (2006) (applying complex adaptive system theory in the context of land use law); *supra* note 13.

15. See Nolon, *supra* note 14, at 20.

16. See generally J.B. Ruhl, *Regulation By Adaptive Management—Is It Possible?*, 7 MINN. J. L. SCI. & TECH. 21 (2005).

vironmental intervention should ideally follow assessment that takes full account of: (1) how the networked components of regional ecosystems work laterally, (2) how the systems work over ecologically meaningful periods of time, and (3) how remote network factors may intervene from beyond the forward linear path of conventional causal assessment.

By their compelling testimonials to the Natural Resources Law of Unintended Consequences, the losses of the Louisiana and Chesapeake wetlands demonstrate the importance of environmental assessment along all three dimensions. The Gulf Coast story stands for the importance of expanding assessment laterally—through the full chain of regional ecosystem interconnectivity by which apparently disparate natural systems are actually causally linked. The Chesapeake story stands for the importance of expanding assessment temporally forward—over time horizons that may exceed the general frame of reference for other kinds of policymaking—and urges greater assessment sensitivity to causal factors that may intervene from unanticipated corners of the network.

On the basis of these cautionary tales, this article suggests that natural resource planners expand on traditional assessment technique toward a model that better tracks the network relationships between the causally integrated components of regional ecosystems. Whereas traditional causal assessment begins with the proposed action and traces only those potential impacts that flow forward in time from the proposal, the Chesapeake story shows that some natural resource management strategies are doomed by network interplay that will not appear in this forward-limited chain of projected events. A better approach would also consider how remote network factors might independently interfere with the success of the proposal. In other words, rather than simply considering what undesirable results might flow forward from the proposed action, assessment should also ask what foreseeable network factors might intervene, at any point in time, that could cause the proposed action to become, itself, undesirable.

Such causally ambidextrous assessment techniques are frequently used in consumer product designs, in which testers consider not only such harms as the product might cause, but also what uses might harm the product, what circumstances might arise in which the product could be misused, and the circum-

stances in which product use might fully backfire, producing a result opposite the product's intended purpose.¹⁷ For its rigorous approach to this third line of inquiry, the quality assurance process of computer programming provides a particularly useful example on which to base a network-integrated model of environmental assessment.¹⁸ Software testers do more than ask what problems a given program might cause within its network environment; they also ask what in the network environment might cause problems for the program.¹⁹

But this network model of expanded assessment is hardly the invention of professional technocrats; it is also the careful strategy of weighing possibilities and testing alternatives that most of us regularly employ whenever faced with important decisions along our personal paths. Ideally, so powerful a tool of good decision making should also be a regular part of natural resource planning. Although expanded assessment poses the formidable problems of cost-control and limit-setting, assessment ambitions can be checked by strategic coupling with risk analysis and a carefully considered boundary of proximate causation. Moreover, the long-term savings enabled by expanded assessment practices will offset this initial investment, as the lost opportunity to better protect New Orleans so powerfully demonstrates.

Indeed, the message of the lost Louisiana and Chesapeake wetlands is that more ambitious environmental assessment has been made necessary by our own increasing power to alter the natural environment. The efficacy with which we have reshaped the Mississippi Delta since resource planning began in New Orleans—and the resulting devastation of the City after Hurricane Katrina—shows that we have simply become too effective at natural resource management, and that assessment technique must advance to match our awesome capacity for environmental modification. When well-intended natural resource law can hasten the drowning of a great city and further endanger the nation's largest estuary, we should rightly ask more from natural resource planning.

17. *See infra* Part IV.

18. *Id.*

19. *Id.*

Part II reviews the Natural Resources Law of Unintended Consequences in action in Louisiana, and highlights the importance of laterally expansive environmental assessment. Part III reviews how the Law of Unintended Consequences persists in the ongoing Chesapeake Bay story, despite the acknowledged lessons from the Gulf Coast. The Chesapeake story highlights the importance of both temporally expansive assessment and assessment more sensitive to factors that might undermine a management strategy from beyond the narrow path considered by traditional linear assessment. Part IV proposes that natural resource planning adopt assessment techniques that expand from the traditional linear model to a network-based model that, coupled with limiting risk analysis, would take better account of the causal factors that might lead us, however inadvertently, toward unintended consequences.

II. UNINTENDED CONSEQUENCES AND LOUISIANA: COASTAL WETLAND LOSS AND THE FLOODING OF NEW ORLEANS

Our first cautionary tale involves the wetlands of southern Louisiana that fringe the Gulf Coast. Before western settlement, these expansive wetlands extended over some five million acres of marshy, vegetated hydric soils²⁰ buffering the Louisiana lowlands, including the present City of New Orleans, from the wind and waters of the Gulf. The wetlands were themselves protected from the force of the sea by a series of barrier islands that have also mostly succumbed to more recent human intervention. Today, these wetlands exist as a fraction of their pre-settlement state, covering only 1,730,000 acres,²¹ fragmented by marine incursion and weakened by the network of pipelines that have been laid beneath them. More than 800,000 acres were lost between 1900–1980,²² and nearly as much has been lost since 1980.²³ Sci-

20. Houck, *supra* note 8, at 7.

21. Gaylord Nelson Institute for Environmental Studies, University of Wisconsin-Madison, Case Studies: The Louisiana Coast, http://www.ies.wisc.edu/international/landscape/case_study_Louisiana.htm (last visited Apr. 5, 2006) (offering the figure at 7,000 square kilometers, which I have converted to acres; 1 square kilometer is 247 acres).

22. Houck, *supra* note 8, at 11.

23. Based on the 1983 estimate that forty-seven square miles were disappearing each year, I extrapolate by multiplying that figure by the twenty-three years that have passed, and converting miles to acreage (1 square mile is 640 acres).

entists estimate that at the present rate, a full third of what remains will be gone by the year 2050.²⁴

Under the “no net loss” wetlands protection policy heralded by the federal government since the first Bush Administration,²⁵ developers must seek permits from the Army Corps of Engineers before converting wetlands to more solid ground with fill.²⁶ But most southern Louisiana wetlands are not disappearing under shopping malls and planned neighborhoods. Instead, they are disappearing into the open waters of the Gulf of Mexico. And as television viewers across the globe witnessed in horror last September, their disappearance contributed to the most devastating natural disaster in the history of the United States, the catastrophic flooding of New Orleans after Hurricanes Katrina and Rita.

Tragically, the collapse of these coastal wetlands is the ultimate but unintended consequence of the success of centuries of natural resource management efforts to contain the seasonal movement of the Mississippi River into its floodplain. The tale of the lost Louisiana wetlands is thus also the story of old-fashioned, single-issue natural resource management colliding with the technological forces of modernity that make single-issue natural resource management no longer possible. In “single-issue” management, early natural resource managers fallaciously assumed that they could alter one feature in an ecosystem without impacting other features within the system. But Katrina brought home that we have simply become too good at what we do—too effective at natural resource management—to ignore the systemic consequences of management choices that alter any one of the many interdependent components of an ecosystem.

24. See United States Army Corps of Engineers News Orleans District, Louisiana Coastal Area Ecosystem Restoration Project, <http://www.mvn.usace.army.mil/prj/lca/> (last visited Apr. 5, 2006) (“As a result of the human activities and natural coastal processes, during the past century the state of Louisiana lost between 600,000 and 900,000 acres of valuable coastal vegetative wetlands. Estimates reveal that another 342,000 acres will be lost between now and the year 2050.”); see also Viguerie, *supra* note 2, at 85.

25. JULIE M. SIBBING, NATIONAL WILDLIFE FEDERATION, NOWHERE NEAR NO-NET-LOSS (2004), http://www.nwf.org/nwfwebadmin/binaryVault/Nowhere_Near_No-Net-Loss.pdf.

26. See, e.g., 33 U.S.C. § 1344 (2000).

A. *Channelizing the Mississippi River*

The Louisiana wetlands are disappearing in the wake of one of the most ambitious natural resource management efforts in the history of the world: the centuries-long campaign to control massive seasonal flooding by the Mississippi River into the great agricultural and industrial regions established in its floodplain and culminating in the Great City of New Orleans at its mouth.²⁷

The largest river in the country,²⁸ the Mississippi drains nearly half the continental United States into the Gulf of Mexico.²⁹ But the mighty Mississippi is not just moving water; it is also moving mud, or sediments, funneling them through its giant network of tributaries into the Mississippi Delta near New Orleans.³⁰ This is the natural pattern of “alluvial rivers” like the Mississippi. The water coursing through an alluvial river scours the bottom of the watercourse, moving sediments ever downstream.³¹ The physical dynamics of moving water deposits the sediments on forward stretches of bed and in point bar formation, exaggerating bends over time, changing the very course and shape of the river.³² These sediments, together with those washed in by storm water, are ultimately deposited as the rich agricultural soils at the delta.

In this way, the Mississippi deposits nearly half a million tons of sediment into the delta each day.³³ Over the last five thousand years, the river has built some 19,000 square miles of southern Louisiana³⁴—roughly the 300 coastal miles between Texas and Mississippi, and the 50 miles inland.³⁵ And until recently, it has sustained this vertically accreted land against the natural forces

27. See, e.g., Houck, *supra* note 8, at 16–18.

28. James G. Wiener et al., U.S. Geological Survey, Status and Trends of the Nation’s Biological Resources, <http://biology.usgs.gov/s+t/SNT/noframe/ms137.htm> (last visited Apr. 5, 2006).

29. Nat’l Park Serv., General Information About the Mississippi River, <http://www.nps.gov/miss/features/factoids/> (last visited Apr. 5, 2006).

30. Viguerie, *supra* note 2, at 86.

31. See *id.*

32. See *id.*

33. See, e.g., 151 Cong. Rec. § 874 (daily ed. Feb. 2, 2005) (statement of Sen. Landrieu) [hereinafter Landrieu].

34. See Houck, *supra* note 8, at 22.

35. Interview by David Brancaccio with Ted Falgout, Denise Reed, Daniel Zuerdling and Oliver Houck, PBS NOW: NEW ORLEANS AND THE DELTA (PBS television broadcast, Sept. 2, 2005), available at http://www.pbs.org/now/transcript/transcriptNOW135_full.html [hereinafter Brancaccio].

of erosion by periodically flooding its banks and replenishing the soil with more sediment.³⁶

In addition to depositing sediment directly at the mouth of the river, the Mississippi replenishes the lands in its floodplain through a cyclical process of flooding.³⁷ Periodically, after especially wet seasons in the uplands, the increased volume of water forces the river beyond its usual banks and flows out over the adjacent lands, or floodplain.³⁸ Such regular flooding maintains healthy riparian wetlands in two ways: it keeps them moist with water content, and just as importantly, it adds rich, new soil on a regular basis.³⁹ In its pre-settlement state, the Mississippi Delta and floodplain were thus characterized by moist, loosely packed wetlands soils, and corresponding riparian vegetation.⁴⁰

This natural cycle of flooding and deposition produced the most active land-building region in North America, which proceeded unimpeded until European settlement around the turn of the eighteenth century. When Spanish explorers first visited in 1543, they arrived during a flood, found the Native Americans storing their belongings in trees, and promptly departed for dryer pastures.⁴¹ The French arrived at the lowlands that would become New Orleans during the dry autumn months of 1718.⁴² At that time of year, the point at which the great river emptied into the sea appeared a particularly auspicious location for a commercial port city—so the French colonists began to build.⁴³ The next spring, when the river spilled from its autumn banks into the spring floodplain—just as it had done for thousands of years—the colonists found themselves in the water.⁴⁴

But the settlers were resourceful, and not easily deterred. To prevent further flooding, they built a small, earthen wall between the river and their homes—a levee.⁴⁵ All was well for a few years until the next particularly rainy season, when the settlement was

36. Viguerie, *supra* note 2, at 86.

37. *Id.*

38. *See id.*

39. *See id.*

40. *See id.*

41. Houck, *supra* note 8, at 17–18.

42. *Id.* at 18.

43. *Id.*

44. *Id.*

45. *See id.*

again flooded by waters that reached the floodplain from farther upstream beyond the levee.⁴⁶ The floodplain, naturally, sloped downward in elevation from these uplands all the way to the sea—and right over New Orleans. So the settlers rebuilt the levee a little higher and extended it a little farther upstream and continued in this pattern.⁴⁷ By the mid-1700s, the levee extended thirty miles from New Orleans.⁴⁸ By 1828, the river was walled on both sides from New Orleans all the way to Baton Rouge.⁴⁹

Over the next three hundred years, the levees grew higher and higher and moved further and further upstream to protect development all along the river floodplain, effectively “channelizing” the river by constraining its natural pattern of alluvial deposition and accretion.⁵⁰ By the early twentieth century, the U.S. Army Corps of Engineers had taken over the project of managing the flood control works, constructing new levees in 1911 and 1926, now with the additional purpose of promoting deep water navigation.⁵¹ After the river managed to jump even the higher confines of the twentieth-century levees in 1950, the Army Corps of Engineers applied itself to better protect “the National interest in controlling the mighty river,”⁵² and further improved the flood control works that already were, from an engineering standpoint, brilliant.⁵³ And alas, here is where the Natural Resources Law of Unintended Consequences sets in.

B. *Flood Control Intensifies the Great Flood*

In the short term, flood control efforts were generally effective⁵⁴—the river was successfully channelized within the levee system and seasonal flooding was contained, allowing for

46. *Id.*

47. *See id.*

48. *Id.*

49. *Id.*

50. *See* Nat'l Wetlands Research Ctr., U.S. Geological Survey, Land Sinks, Waters Rise, Coastal Wetlands Disappear, <http://www.lacoast.gov/watermarks/2005-08/1wetlandsDisappear/index.htm> (last visited Apr. 5, 2006).

51. *See* Houck, *supra* note 8, at 19–21.

52. *Id.* at 18 (quoting Mississippi River Comm'n, U.S. Army Corps of Mississippi River and Tributaries Project, *Cario to the Gulf* (1977)).

53. *E.g.*, John McQuaid & Mark Schleifstein, *Shifting Tides*, *TIMES-PICAYUNE* (New Orleans), June 26, 2002, at 14.

54. Even so, the river overflowed the levees and caused widespread damage in 1849 and 1950, when flood heights topped walls that would have sufficed but for continuing extensions upstream. *See* Houck, *supra* note 8, at 18.

system and seasonal flooding was contained, allowing for the expansion of homes and businesses into the plentiful river floodplain.⁵⁵ But when the seasonal flooding ceased, so did the annual deposition of moisture and bedload into the floodplain and delta soils.⁵⁶ This caused two problems, now made famous by the post-Katrina plight of New Orleans.

First, as the formerly moist wetland soils began to dry out, they started to lose loft, sinking down a bit.⁵⁷ Soil compaction of this sort may prove of little consequence in the uplands, but as history witnessed after Hurricanes Katrina and Rita, even a small loss of elevation is of great consequence in the delta lands around New Orleans that were already very close to sea level.⁵⁸ But soil compaction was not the only cause for concern. In addition, the natural forces of wind and water erosion, to which the soil is constantly subject, were no longer being counterbalanced by the regular deposition of river sediment that had formerly sustained it.⁵⁹ As one narrative compellingly tells it, the interruption of the river's seasonal flooding was tantamount to putting the riparian and coastal wetlands on a starvation diet.⁶⁰

As a result of these two factors, the lands have been gradually subsiding at ten times the normal rate over the last century.⁶¹ More and more of the greater New Orleans area suffered gradual elevation loss, falling below sea level.⁶² Indeed, just how much of New Orleans now sits below sea level was made devastatingly clear during the aftermath of Hurricane Katrina, when mechanical pumps struggled to move water out of the basin lowlands.⁶³ But New Orleans is at least a basin, ringed with higher elevation lands that generally keep the sea at bay.⁶⁴ The true margin between the land and the sea—the coastal wetland—is simply receding into the open water.⁶⁵ As the soil continues to subside and

55. Mark Fischetti, *They Saw it Coming*, N.Y. TIMES, Sept. 2, 2005, at A23.

56. *See* Viguerie, *supra* note 2, at 86.

57. *See id.*

58. Dean & Revkin, *supra* note 9.

59. Viguerie, *supra* note 2, at 85–86.

60. Brancaccio, *supra* note 35 (interviewing Oliver Houck).

61. Dean & Revkin, *supra* note 9.

62. *E.g.*, Evan Thomas, *The Lost City*, NEWSWEEK, Sept. 12, 2005, at 45.

63. *E.g.*, Evan Thomas, *How Bush Blew It*, NEWSWEEK, Sept. 19, 2005, at 33–35.

64. McQuaid & Schleifstein, *supra* note 53.

65. *See id.*

the sea inundates the lowest-lying wetlands below New Orleans, coastal marshes are crumbling into the sea.⁶⁶ In the last century, these wetlands have been sinking into the sea at the rate of an area the size of some forty football fields each day.⁶⁷

The coastal wetlands already weakened by river channelization were further undermined by the final subject of natural resource management in the delta, the discovery of rich stores of carbon-based fuels. Thanks to the proximity of these stores to the Port of New Orleans, the delta region became perhaps the most important energy hub in the continental United States, supplying nearly twenty percent of domestic demand for oil and natural gas.⁶⁸ As a result, beginning in the 1930s and accelerating after the 1950s,⁶⁹ some 20,000 miles of oil and gas pipeline were laid through these coastal marshes,⁷⁰ which further weakened any resilience to erosion left in the wetlands. The Army Corps of Engineers now estimates that by 2040, the shoreline may advance landward by as much as thirty-three miles.⁷¹

Coastal wetlands provide many important natural resource services, but Hurricane Katrina demonstrated the especially grave consequences of coastal wetland loss for the City of New Orleans. In addition to providing wildlife habitat and water filtration, one of the most important ecosystem services that wet-

66. Nat'l Wetlands Res. Ctr., U.S. Geological Survey, *Stemming the Tide: The Mississippi River Delta and the Davis Pond Freshwater Diversion Project*, <http://www.lacoast.gov/programs/DavisPond/stemming-the-tide.htm> (last visited Apr. 5, 2006) [hereinafter *Stemming the Tide*].

67. *Id.*

68. Viguerie, *supra* note 2, at 86.

69. Houck, *supra* note 8, at 27–28.

70. *Stemming the Tide*, *supra* note 66.

Whereas the levees lessen the flow of *fresh water* into wetlands, channels dredged for commercial shipping and oil extraction have created new pathways for the flow of *salt water* into the coastal interior. In the latter half of the 20th century, a pattern emerged. Areas once dominated by freshwater marshes experienced conversion to more salt-tolerant species. Brackish marshes converted to saltwater. The heightened salinities killed off the existing vegetation, causing the root systems that bind the submerged soil to decay. And because the yearly sediment deposits were no longer there to counter the ongoing wind and wave erosion at the delta's edge, soil substrates anchoring exposed marshes were simply washed away, converting once functional wetlands into open water.

Id.

71. See Hope Babcock, *Federal Wetlands Regulatory Policy: Up to Its Ears in Alligators*, 8 PACE ENVTL. L. REV. 307, 315 (1991).

lands provide is—ironically—flood control.⁷² By crude analogy, coastal wetlands serve as giant sponges—or the doormat at a threshold, absorbing the stormwater that you do not want to bring in with you. And when hurricanes come ashore, they help absorb the impacts of storm surge.⁷³

As we learned during the hurricane season of 2005, the greatest source of disaster for New Orleans during both Katrina and Rita was the storm surge, the bulge of water raised over normal tide levels by the upward funnel effect of hurricane winds.⁷⁴ Hurricane Katrina raised the surge twenty-nine feet over normal tide levels, enough to weaken and breach the levees holding Lake Pontchartrain back from New Orleans.⁷⁵ When the levees were breached, the lake emptied into the bowl-shaped city, now farther below sea level than it had been even at the time it was first settled due to the soil subsidence effect of the river's channelization.⁷⁶ Because the city was below sea level, the water could not drain out of it by gravity alone; indeed, this was a feat requiring months of mechanical pumping.⁷⁷ It was thus that, despite the best of natural resource management intentions, aggressive flood control efforts along the Mississippi River inadvertently ripened the conditions that led to the great flooding of New Orleans after Katrina.

The loss of Louisiana's coastal wetlands portends other important regional problems as well. For example, the 20,000 miles of oil and gas pipelines laid through the coastal marshes were not built to withstand exposure to the open ocean, but many are now located in the middle of the Gulf of Mexico—causing great concern at Port Fourchon, the command center of the Gulf Coast oil and gas industry.⁷⁸ Leaks and breakages are inevitable, and some occurred after Katrina.⁷⁹ Spills not only contaminate water supplies and wildlife habitat, but they also kill the very marsh vege-

72. TABB & MALONE, *supra* note 4, at 642.

73. Dean & Revkin, *supra* note 9.

74. Thomas, *supra* note 62, at 49 illus. (showing storm surge).

75. *Id.* at 46.

76. *See generally, id.* at 42–52.

77. *See, e.g.,* Thomas, *supra* note 63, at 33–35.

78. *See* Landrieu, *supra* note 33.

79. *See* MEMBERS SCHOLARS OF THE CTR. FOR PROGRESSIVE REFORM, AN UNNATURAL DISASTER: THE AFTERMATH OF HURRICANE KATRINA 17 (2005), available at http://www.progressiveregulation.org/articles/unnatural_Disaster_512.pdf.

tation that helps bind coastal wetlands against erosion.⁸⁰ The vicious cycle thus progresses: degrading wetlands makes oil pipelines vulnerable to fracture, which further degrade the wetlands in which they are laid, making them even more vulnerable to fracture, and so on.

In addition, coastal wetlands provide an important buffer against land-based marine pollution by filtering contaminants out of stormwater that passes over developed lands and into the Gulf.⁸¹ Fewer wetland water purification services means greater loads of pollutants enter coastal waters, adversely affecting the health of marine ecosystems and commercial harvests of oysters, shrimp, and the other species that form twenty-eight percent of the nation's total fishery yield.⁸² Coastal wetlands also provide critical habitat for both land-based and marine species that breed and feed in coastal marshes⁸³ and serve as nurseries for ninety-six percent of all commercial species and fifty percent of recreationally fished species in the Gulf region.⁸⁴ Half of all migratory water birds in North America use the Mississippi Flyway and depend on the coastal marshes for sustenance during their journey.⁸⁵ Moreover, the massive bedload that once replenished the Mississippi floodplain now flows directly into the Gulf of Mexico, which may create other hazards for reef ecosystems.⁸⁶

C. Coping with Coastal Land Loss

If anything, the tragedy of New Orleans is not that the original European settlers could not have foreseen the results of the well-intended flood control policies that they set in motion, but that the flood control managers of the late twentieth century *could*

80. Houck, *supra* note 8, at 59–64.

81. *E.g.*, E.P.A., Wetlands, Functions and Values, <http://www.epa.gov/water/train/wetlands/module05.htm> (last visited Apr. 5, 2006).

82. Houck, *supra* note 8, at 84–85.

83. Viguerie, *supra* note 2, at 85.

84. Houck, *supra* note 8, at 82.

85. *See id.*

86. *Cf.* Robin Kundis Craig, *Protecting International Marine Biodiversity: International Treaties and National Systems of Marine Protected Areas*, 20 J. LAND USE & ENVTL. L. 333, 346 (2005) (“Land-based air pollution can . . . acidify ocean waters, increase the concentration of heavy metals and other toxic pollutants in the oceans, and increase sedimentation of the oceans, blocking sunlight, interfering with photosynthesis, and smothering coastal ecosystems such as coral reef.”).

foresee the problem, but were unable to take the necessary steps to reverse it. Indeed, a number of restoration programs have emerged over the last twenty years in response to Louisiana's coastal land loss crisis, although funding has not materialized at levels necessary to implement them on a meaningful scale.

The Coastal Wetlands Planning, Protection and Restoration Act ("the CWPPRA"), also known as the "Breaux Act," was authorized by Congress in 1990 to address wetland loss nationally with a primary focus on coastal Louisiana.⁸⁷ The CWPPRA is administered by a task force consisting of representatives from the Army Corps of Engineers, the Environmental Protection Agency, the Department of Commerce, the Department of the Interior, the Department of Agriculture and the Louisiana Governor's Office.⁸⁸ A total of 149 projects have been authorized through the CWPPRA since 1990, benefiting more than 135,000 acres of coastal wetlands.⁸⁹ One promising experiment is the Caernarvon project, a \$26 million demonstration project that enables carefully controlled flooding of adjacent delta wetlands.⁹⁰ A massive gate in the side of a levee is periodically opened to release river waters rich with bedload over the wetland soils, enabling them to be replenished with the sediment that has bypassed them for the last hundred years.⁹¹ However, Caernarvon's approach is of limited value in floodplain areas that have already been developed with homes and businesses.

Accordingly, the State of Louisiana collaborated with several federal agencies in designing a strategic plan for coping with land loss on a more regional basis, *Coast 2050: Toward a Sustainable Coastal Louisiana*.⁹² The plan outlines seventy-seven ecosystem restoration strategies that are needed to protect and sustain the

87. See 16 U.S.C. § 3952 (2000).

88. *Id.* § 3951.

89. Letter from Dr. Erik Zobrist, Director of the National Ocean and Atmospheric Administration's restoration efforts in Louisiana under the Coastal Wetlands, Planning, Protection and Restoration Act, to author (October 19, 2005) (on file with author) (providing information on current efforts to deal with the coastal land loss crisis in Louisiana).

90. Press Release, U.S. Geological Survey Nat'l Wetlands Res. Ctr., Caernarvon Project Given an "A" by Coastal Specialists (Oct. 27, 1997), available at <http://www.lacoast.gov/news/press/1997-10-27.htm>.

91. See generally Nat'l Wetlands Res. Ctr., U.S. Geological Survey, Caernarvon Freshwater Diversion Project, <http://www.lacoast.gov/programs/Caernarvon/factsheet.htm> (last visited Apr. 5, 2006).

92. See Nat'l Wetlands Res. Ctr., U.S. Geological Survey Coast 2050, Project Overview (2004), <http://www.coast2050.gov> (last visited Apr. 5, 2006).

remainder of Louisiana's coastal wetlands. Construction costs of the Coast 2050 plan have been estimated at approximately ten times the annual level of CWPPRA spending, or \$14 billion dollars over the next thirty years.⁹³ The Louisiana Coastal Area ("the LCA") Louisiana Ecosystem Restoration Study was initiated as the blueprint for implementing Coast 2050 restoration strategies into a series of large-scale projects for coastal Louisiana.⁹⁴ In 2003, however, the White House reduced funding for coastal protection programs in Louisiana.⁹⁵

D. *Lessons from Louisiana: Laterally Expansive Environmental Assessment*

What can we learn from this particularly dark demonstration of the Natural Resources Law of Unintended Consequences? For one thing, now that estimates for post-Katrina repairs have reached \$200 billion,⁹⁶ the \$14 billion contemplated for the Coast 2050 plan suddenly seems like a better deal.⁹⁷ Thus, the first lesson to take from the tragic flooding of New Orleans is the impor-

93. See Fischetti, *supra* note 55.

94. See LOUISIANA COASTAL AREA, U.S. ARMY CORPS OF ENG'RS, LOUISIANA ECOSYSTEM RESTORATION STUDY (2004), available at http://data.lca.gov/Ivan6/main/main_exec_sum_toc.pdf.

95. See Ron Fournier, *Who Failed the People of New Orleans*, ASSOC. PRESS, Sept. 1, 2005, available at http://www.ksdk.com/news/news_article.aspx?storyid=84164 ("Just last year, the Army Corps of Engineers sought \$105 million for hurricane and flood programs in New Orleans. The White House slashed the request to about \$40 million. Congress finally approved \$42.2 million, less than half of the agency's request."); Susan B. Glasser & Sash White, *Storm Exposed Disarray at the Top*, WASH. POST, Sept. 4, 2005, at A01 (noting budget cuts for natural disaster response agencies); see also Thomas, *supra* note 62, at 46. In 2004, a final LCA report was released that included five "near-term" critical restoration initiatives and additional funding for research and feasibility studies. LOUISIANA COASTAL AREA, *supra* note 94, at viii. In addition, the Water Resources Development Act (the "WRDA") is the primary mechanism through which the U.S. Army Corps of Engineers is funded for conducting flood control, navigation and environmental restoration projects. See Water Resources Development Act of 2000, Pub. L. No. 106-541, §§ 101-112, 114 Stat. 2572, 2572-87 (authorizing water resources as development and conservation and other projects). The Act is typically reauthorized on a four-year basis. In 2000, the WRDA provided a fifty percent federal cost-share for the \$7.8 billion Comprehensive Everglades Restoration Plan. See *id.* § 601(e), 114 Stat. at 2684. Funding for the LCA program has not been forthcoming, however, as Congress failed to pass WRDA legislation in 2004. See S. 2773, 10th Cong. (2004); [103th Congress] Cong. Index (CCH) 20,526 (Dec. 30, 2004) (showing that the statutes of S.2773 never passed placement on the senate calendar); see also Letter from Dr. Erik Zobrist, NOAA, to author, *supra* note 89.

96. Howard Fineman, *Money, Money, Everywhere*, NEWSWEEK, Sept. 26, 2005, at 27.

97. That said, Katrina would certainly have caused some damage even if the coastal wetlands had been intact, so these figures cannot be considered mutually exclusive.

tance of accounting for the true value of ecosystem services, such as the flood control protection offered by coastal wetlands, in the cost-benefit analyses that are now customary in natural resource management. An earlier investment in protecting Gulf Coast wetlands might have paid substantial dividends in reducing the scope of post-Katrina flood damage.

However, the primary lesson from Louisiana's experience is to avoid making important natural resource management decisions in the vacuum of old-fashioned, single-issue natural resource management. Measured both by our ability to understand the complex nature of ecosystems and our capacity to alter them, we have outgrown the comfortable but false isolation of single-issue management. The Louisiana story teaches the importance of laterally expansive natural resource planning: planning that considers the reverberations of management strategies beyond the single resource management objective and throughout the affected regional ecosystem. After all, it defeats the purpose of a flood control program if preventing the river's seasonal flooding merely leads to catastrophic flooding of an even less predictable sort.

Indeed, the importance of broader natural resource planning was recognized in 1970, when the National Environmental Policy Act ("NEPA") was enacted by overwhelming bipartisan majorities in both houses of Congress, requiring that government decisions be taken with an informed and long-term view toward environmental consequences.⁹⁸ Under NEPA, a federal actor considering an action that might have negative consequences for the environment must first assess whether potential environmental impacts might reach a designated threshold of "significance."⁹⁹ If significant environmental impacts are likely, the actor must then analyze the potential consequences and consider alternatives that might pose lesser impacts in an Environmental Impact Statement.¹⁰⁰ Although NEPA requires time and resource-consuming analysis, it has been accredited as the most successful environmental law in the history of the world, altering the very culture of government towards greater accountability and long-term plan-

98. The National Environmental Policy Act of 1969, 42 U.S.C. § 4321 (2000).

99. 42 U.S.C. § 4332(c) (2000).

100. *Id.*

ning, and has been imitated by nearly half of all American states and many other nations.¹⁰¹

It goes without saying that the French settlers who built the first levee in 1718 may not have appreciated alluvial river hydrology in all the glory that we do now, and the state of the science might not have enabled nineteenth-century flood control engineers to foresee the unintended consequences to coastal wetlands even had they been subject to NEPA's planning requirements.¹⁰² Still, the science certainly caught up with the problems well before Katrina fully exposed New Orleans's vulnerability, and the failure to adequately explore countervailing measures is a more culpable natural resource management choice.¹⁰³ Disputes over levee management decisions by the Army Corps after NEPA's passage reveal continuing concern over the quality of environmental assessment that accompanied management of the Mississippi¹⁰⁴ (although, even if additional planning missteps came later, the critical management decisions that doomed the Gulf Coast wetlands—those to fully channelize the River—had already been made).

101. See Oliver A. Houck, 11 DUKE ENVTL. L. & POL'Y F. 173, 173–74 (2000) (reviewing LYNTON KEITH CALDWELL, *THE NATIONAL ENVIRONMENTAL POLICY ACT: AN AGENDA FOR THE FUTURE* (1998)) (noting that NEPA is both “the most successful environmental law in the world” and the most imitated—but also the most disappointing, to the extent that its procedural mandate lacks substantive teeth).

102. The bulk of the Mississippi River Flood efforts took place in the late nineteenth century, long before passage of NEPA. See McQuaid & Schleifstein, *supra* note 53. NEPA was signed into law on January 1, 1970. See Task Force on Improving the National Environmental Policy Act, History in Brief (NEPA), <http://resourcescommittee.house.gov/nepataskforce/history.htm> (last visited Apr. 5, 2006).

103. For example, Houck, *supra* note 8, described the crisis of Louisiana's coastal land loss, its causes, and implications with frightening accuracy in 1983. There is almost nothing we know now that we did not know then, yielding almost twenty-five years of opportunity to forestall the consequences that have now befallen New Orleans.

104. See *Save Our Wetlands, Inc. v. Rush*, 424 F. Supp. 354 (E.D. La. 1976). In this case, the Army Corps of Engineers was enjoined from proceeding with a flood control management strategy that failed to meet NEPA's requirements for environmental assessment. Rather than complete the environmental assessment as required by the statute, the Army Corps decided not to proceed on the proposed plan. Following Katrina, the case became a rallying cry among opponents of NEPA, who argue that the delay and expense associated with required environmental assessment helped contribute to the flooding of New Orleans by interfering with the Corps' ability to efficiently implement a new management plan. Advocates for NEPA counter that the fault lies with the Army Corps for opting to discontinue planning rather than comply with the law. Indeed, considering the history presented here of poorly planned management strategies in the Mississippi Delta, it seems all the more important that environmental assessment be performed to the highest standard of care.

But now that we understand the relationship between coastal wetland flood control services and river channelization, we certainly cannot allow ourselves to make this particular mistake again. New Orleans's example stands as a cautionary tale to motivate more careful assessment and decision-making in other management realms that implicate cross-media or regional ecosystemic relationships (for example, the potential relationship between air pollution and sea level rise, as mediated by climate change, or the relationship between municipally regulated land uses and federally regulated stormwater pollution). Moreover, the tragic flooding of New Orleans offers heart-rending testimony to the continued importance of heeding the long-term consequences of resource management choices that are easy to miss in the heat of short-term problem-solving efforts. Although costly investment in Coast 2050's restoration projects may have seemed less beneficial than simply maintaining the levees in 2003, Katrina certainly revealed the "penny-wise, pound-foolish" nature of that decision.

The tale of Louisiana's lost wetlands thus highlights the importance of thinking progressively through the lateral ecosystemic consequences of policy decisions. This is a natural resources planning goal toward which the environmental review process under NEPA aspires; indeed, NEPA and other natural resource planning laws that require policymakers to reflect on future environmental consequences¹⁰⁵ have forestalled countless indirect but foreseeable catastrophes that might have followed from single-issue planning.¹⁰⁶

Nevertheless, as this piece goes to press, a Congressional Task Force is proposing that Congress streamline NEPA by reducing its assessment requirements.¹⁰⁷ At the very time that the cau-

105. In addition to the many state statutes modeled after NEPA, other natural resource planning statutes include directives in the Coastal Zone Management Act, 16 U.S.C. § 1452(3); the National Forest Management Act, 16 U.S.C. § 1604(a); the Federal Land Policy Management Act, 43 U.S.C. § 1712; the National Wildlife Refuge Improvement Act, 16 U.S.C. § 668dd; and the Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. 1853(a).

106. See ROBERT G. DREHER, *NEPA UNDER SIEGE: THE POLITICAL ASSAULT ON THE NATIONAL ENVIRONMENTAL POLICY ACT 5-7* (2005), available at http://www.law.georgetown.edu/gelpi/news/documents/NEPAUnderSiegeFinal_000.pdf.

107. The House of Representatives Committee on Resources is currently considering recommendations by its NEPA task forces to expand exemptions from NEPA review, limit citizen-standing to raise legal challenges under NEPA, limit the scope of alternatives analyses, and limit the consideration of cumulative impacts. See H.R. COMM. ON RES.,

tionary tales from New Orleans and the Chesapeake herald the importance of more thorough environmental assessment, it would be ironic if federal requirements for environmental assessment were weakened in the primary federal natural resources planning statute.

Still, even NEPA exempts actions taken solely to protect the environment, making them potentially more vulnerable to the Law of Unintended Consequences if the management efforts are taken for no other purpose than environmental protection. Such would have been the case, for example, in the Chesapeake wetlands preservation plan that is the protagonist in the other of our tale of two wetlands. The Chesapeake tale further suggests that conventional environmental assessment may not be enough to identify foreseeable but unintended consequences in any event. Thus, effective natural resources planning must continue to evolve, even if it must do so independently of NEPA. To avoid unintended consequences, smart planners may need to press assessment beyond the statutory minimum and toward best practices that will better advance long-term management goals.

III. UNINTENDED CONSEQUENCES AND THE CHESAPEAKE: THE INADVERTENT DEPLETION OF PROTECTED TIDAL WETLANDS

The lost Louisiana wetlands demonstrates the instability of single-issue natural resource management, where all attention was focused on the management of the river and none spared for the consequences of the changed river dynamics on the rest of the natural system. Such an accident in policymaking may be forgivable as a vestige of history before the modern era of earth science and environmental assessment. Nevertheless, the Chesapeake story demonstrates that we remain vulnerable to the Natural Resources Law of Unintended Consequences even in our state of relative natural resource planning sophistication.

109TH CONG., TASK FORCE ON IMPROVING THE NATIONAL ENVIRONMENTAL POLICY ACT AND TASK FORCE ON UPDATING THE NATIONAL ENVIRONMENTAL POLICY ACT, INITIAL FINDINGS AND DRAFT RECOMMENDATIONS, 26–29 (Dec. 21, 2005), *available at* http://resourcescommittee.house.gov/nepataskforce/report/nepareport_finaldraft.pdf. These recommendations are currently in the forty-five-day period allocated for public comment; they have not yet been adopted by the Committee. *Id.* at 1. If adopted, these amendments would significantly weaken the quality of long-term environmental assessment required under the statute.

When policymakers began to recognize the importance of wetlands in the late 1970s, they championed a number of natural resource management policies to afford greater protections for those wetlands that still remained after centuries of development-induced destruction.¹⁰⁸ Many states, including Virginia, passed wetlands management programs that sought to minimize the impact of human activities on tidal wetlands, often by restricting the ability of landowners to build structures within the designated boundaries of such wetlands.¹⁰⁹

Unlike the nineteenth-century flood control efforts on the Mississippi, the natural resource managers who designed these laws were thinking ecosystemically, especially about the important role played by wetlands in buffering the margin between terrestrial and aquatic systems. They had already learned the lesson demonstrated more recently by New Orleans's cautionary tale, and yet even their more laterally expansive natural resource planning led them unknowingly toward an unforeseen (although foreseeable) tragic error. Although they had considered the interplay between the components of the regional Chesapeake Bay ecosystem, what they had not quite thought through was the way the system would behave over *time*, and how intervention by factors from the remote corners of the system might lead to unintended consequences.

A. *Saving the Bay by Protecting the Wetlands*

The Chesapeake Bay is the largest estuary in the United States, spanning more than 4500 square miles within 11,700 miles of coastline (more than the entire West Coast).¹¹⁰ The Bay "supports more than 3600 species of plants, fish and animals, including 348 species of finfish, 173 species of shellfish and over 2700 plant species," and "produces 500 million pounds of seafood" each year.¹¹¹ The Chesapeake is also "home to 29 species of waterfowl and is a major resting ground along the Atlantic Migratory

108. See, e.g., VA. CODE ANN. §§ 28.2-1301 to -1320 (2004).

109. See, e.g., *id.* §§ 28.2-1302, -1306, -1308.

110. ERNST, *supra* note 6, at 9-10.

111. Chesapeake Bay Program, About the Chesapeake Bay—Bay Factoids, <http://www.chesapeakebay.net/info/factoids.cfm> (last visited Apr. 5, 2006).

Bird Flyway,” hosting one million waterfowl every winter.¹¹² Two of the five major North Atlantic ports in the United States, Baltimore and Hampton Roads, are located within the Bay.¹¹³

The Chesapeake is overtly appreciated as a commercial and recreational resource for the fifteen million people who live within its watershed.¹¹⁴ Still, the Bay remains in ecological crisis even twenty years after serious natural resource management efforts were undertaken to reverse the ever-growing “dead zone” in the Bay: the region so polluted that it lacks sufficient oxygen to sustain marine life.¹¹⁵ Over the last four decades, the volume of anoxic water in the Bay has more than tripled.¹¹⁶ In 2005, forty-one percent of the main Bay (approximately 250 square miles) had too little oxygen to support marine life.¹¹⁷

In 1983, the first Chesapeake Bay Agreement established the Chesapeake Bay Program, a voluntary government partnership among Maryland, Virginia, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and the U.S. Environmental Protection Agency, to manage Bay restoration efforts.¹¹⁸ However, the factors that led to the dead zone have been hard to manage away.

The largest contributor to the dead zone is non-point source pollution, or contaminants that are washed off the ground and into waterways from various land uses on lawns, farms, roads, parking lots, and businesses.¹¹⁹ Pollutants like fertilizer, pesticides, and animal waste fuel the excessive growth of algae that then starves the oxygen content of the water needed to sustain

112. *Id.*

113. *Id.*

114. ERNST, *supra* note 6, at 17.

115. See Chesapeake Bay Foundation, The Chesapeake Bay's Dead Zone, http://www.cbf.org/site/PageServer?pagename=resources_facts_deadzone (last visited Apr. 5, 2006).

116. See Chesapeake Bay Foundation, The Chesapeake Bay's Dead Zone, http://www.cbf.org/site/PageServer?pagename=resources_facts_deadzone mainstem (“The Problem in the Mainstem”) (last visited Apr. 5, 2006).

117. Scott Harper, *Chesapeake Bay Again Receives a Grade of “D,”* VIRGINIAN-PILOT (Norfolk, Va.), Nov. 14, 2005, at B1; Letter from Dr. Kirk Havens, Assistant Director, Center for Coastal Resources Management, Virginia Institute of Marine Science, to author (March 13, 2006) (on file with author) (confirming 250 square mile figure).

118. Cynthia J. Aukerman, *Agricultural Diffuse Pollution Controls: Lessons for Scotland from the Chesapeake Bay Watershed*, 20 J. LAND USE & ENVTL. L. 191, 246 (2004).

119. *Id.* at 221–26.

other marine life,¹²⁰ while contamination by motor oils, chemicals, and even tailpipe emissions from automobiles, which enter air currents and eventually fall into the Bay,¹²¹ create a toxic environment unable to sustain any life at all. Demonstrating that one size never fits all in natural resource management, the very movement of sediments needed to sustain the coastal Louisiana wetlands is an increasingly understood source of the Chesapeake's woes, as sediment from coastal erosion, urban development, and agricultural land uses enters and clouds Bay waters such that sunlight cannot penetrate to the food-chain supporting grasses on the Bay floor.¹²² The oyster population that once helped to filter contaminants from the waters began to collapse in 1880, devastating the commercial oyster fishery and compounding the Bay's pollution problems.¹²³

Why such a rapid decline? Part of the reason was that there were more contaminants associated with increased land-based development.¹²⁴ But another reason was that the margin between the contaminating land uses and the waters of the Bay—the wetlands—had been decimated by the same development.¹²⁵ Though providing the critical regional ecosystem services of flood control, pollution mitigation, and habitat for commercially, recreationally, and intrinsically important biodiversity, marshes make for undesirable real estate. They are too soggy to support structures, and so are often filled to allow firm support of structural foundations. To many landowners, vegetated wetlands are not as visually at-

120. *Id.* at 227–28.

121. Chesapeake Bay Program, Bay FAQ, <http://www.chesapeakebay.net/about.htm> (last visited Apr. 5, 2006).

122. Aukerman, *supra* note 118, at 197–98.

123. *Id.* at 202–03 (discussing the collapse of the oyster population); Craig, *supra* note 86, at 352 (explaining the effect on oysters' filtering capabilities).

124. Still, efforts to curtail the march of contaminants into the Bay have not been wholly unsuccessful. The Chesapeake Bay Foundation pointed out in its 2005 Annual "State of the Bay" Report that, in the last forty years, the human population in the watershed has doubled, doubling the automobile traffic and sewage production and claiming nearly half the available open space for development—but the state of the Bay remained in a relatively constant, if miserable, state over the same period of time. While a forty-one percent dead zone is nothing to celebrate, we can at least note that the Bay did not deteriorate to a state twice as bad over the same period of time, and that efforts to halt the decline have met with some success. See Harper, *supra* note 117 (citing CHESAPEAKE BAY FOUNDATION, STATE OF THE BAY 2005 REPORT 2 (2005), available at <http://www.cbf.org/site/DocServer/sotb2005/sotb2005lores.pdf?DOCID=4564>).

125. See James G. Titus, *Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches Without Hurting Property Owners*, 57 MD. L. REV. 1279, 1281 (1998) (noting that the land between development and the Bay is receding).

tractive as the water's edge itself, and so they hardened wetlands with sea walls, bulkheads, and rock structures to produce a clean boundary line at the edge of coastal land.¹²⁶ As Chesapeake Bay Program participants came to realize the importance of wetlands protection as a management tool for resurrecting the Bay, state natural resource managers struggled to determine the best way to protect what wetlands were left against further destruction while finding a way to respect the investment-backed expectations of private property owners with bayside lands.

In 1972, the Commonwealth of Virginia passed a tidal wetlands management program¹²⁷ that sought to minimize the impact of human activities on these wetlands by mandating that the construction of structures in tidal areas take place, to the maximum extent possible, outside of the wetlands.¹²⁸ The law attempted to compromise between the legitimate expectations of landowners to protect and control their private property while providing protections for the wetlands at the edges of private property that serve public interests under Virginia's public trust doctrine.¹²⁹ The common law public trust doctrine has historically protected public interests in navigable waters, especially the right of access.¹³⁰ However, Virginia is one of several states that have constitutionalized even broader protections for the public interests in water, waterways, and other natural resources, as set forth in Article XI, Section 1 of the Virginia Constitution:

To the end that the people have clean air, pure water, and the use and enjoyment for recreation of adequate public lands, waters and other natural resources, it shall be the policy of the Commonwealth to conserve, develop, and utilize its natural resources, its public lands, and its historic and cultural sites and buildings. Further, it shall be the Commonwealth's policy to protect its atmosphere, lands, and waters from pollution, impairment, or destruction, for the benefit, enjoyment, and general welfare of the people of the Commonwealth.¹³¹

126. Interview with Carlton Hershner, Jr., Dir., Ctr. for Coastal Res. Mgmt., Va. Inst. of Marine Scis., and Kirk Havens, Assistant Dir., Ctr. for Coastal Res. Mgmt., Va. Inst. of Marine Scis., in Gloucester, Va. (Nov. 4, 2005) [hereinafter Hershner & Havens].

127. Act of Apr. 10, 1972, ch. 711, 1972 Va. Acts 989.

128. VA. CODE ANN. § 28.2-1303 (2005).

129. The tidal wetlands program is administered by the Marine Resources Commission. See VA. CODE ANN. §§ 28.2-1301 to -1320 (2005).

130. See, e.g., *Ill. Cent. R.R. Co. v. Illinois*, 146 U.S. 387 (1892) (recognizing the American reception of the common law public trust doctrine).

131. VA. CONST. art. XI, § 1.

Article XI, Section 2, addresses conservation and development, as well as the role of the General Assembly in “the furtherance of such policy.”¹³²

Accordingly, much research and a huge state survey of intertidal wetland service function was brought to bear on establishing a scientifically meaningful basis for the jurisdictional boundary of the law, or how much wetland upland from the water’s edge would receive protection. In the end, policymakers defined the upper limit of vegetated wetlands in the Code of Virginia as “one and one-half times the mean tide range.”¹³³ In other words, in the range of wetland that extended upland one and one-half times the mean tide range above the average low water point, no development could occur without a special state permit.¹³⁴ Beyond that jurisdictional line, landowners could build structures or harden shorelines without seeking regulatory permission¹³⁵ (and, in fact, many permits were granted to allow structures within the jurisdictional boundary).¹³⁶

B. *The Unforeseen (Yet Foreseeable) Contingency*

The law was a hard-won compromise, forged in the clash between landowners who sought complete freedom to develop to the edge of the water and others who sought even more serious protection for the public interest in the wetlands at the margin. Assuming that permits to build within the jurisdictional boundary were not too forthcoming, it might have been an optimal compromise between such important competing interests. Private property rights were respected, and the most valuable wetland zones had been identified and were afforded protection. At least, it *would* have been an optimal compromise—if it were really true

132. *Id.* art. XI, § 2.

133. VA. CODE ANN. § 28.2-1300 (2004) (“*Vegetated wetlands*’ means lands lying between and contiguous to mean low water and an elevation above mean low water equal to the factor one and one-half times the mean tide range at the site of the proposed project in the county, city, or town in question . . .”).

134. *Id.* § 28.2-1302 (4.A.) (2004) (“Any person who desires to use or develop any wetland within this [county, city, or town], other than for the purpose of conducting the activities specified in § 3 of this ordinance, shall first file an application for a permit directly with the wetlands board or with the Commission.”).

135. *See id.*

136. Interview with Hershner & Havens, *supra* note 126.

that the most valuable wetland zones had actually been identified and were afforded protection. The problem, as it turns out, is that they had not been properly identified, and were accordingly left vulnerable.¹³⁷ It was not because the massive survey and research effort deployed to establish the mean-high tide metric had been flawed; it was unassailable in its measurements at the time. But times change, and this is what the policymakers missed: the laws were crafted without considering the dynamic nature of intertidal wetlands over time. Even in the three decades that followed the new policy, significant wetland acreage has been lost, and we now understand that all wetlands in the protected zone are at risk of disappearing as an unforeseen result of this policy.¹³⁸

The problem is essentially this: the regulatory plan assumed that the tidal wetlands designated for protection would always be located where they were measured in the initial statewide surveys between 1969 and 1977,¹³⁹ but we now understand that this is simply not the case. Instead, wetlands migrate across the land surface in geologic time with fluctuations in land subsidence and sea level, always occupying the upper intertidal zone at the margin of the sea and land.¹⁴⁰ The law tried to protect the intertidal zone as measured in the 1960s and 1970s, and the short term result was a promising reduction in the amount of construction proposed for these wetlands.¹⁴¹ But an additional consequence was an acceleration of the construction by landowners of shoreline protection structures just landward of the jurisdictional boundary protecting then-existing wetlands.¹⁴² As aforementioned, landowners tend to desire a clear boundary at the edges of their yards, and a hard structure to prevent coastal erosion at the edge

137. *Id.*

138. *Id.*

139. M.L. Wass & T.D. Wright, *Coastal Wetlands of Virginia, 1st Interim Report*, Special Report No. 10 (Va. Inst. of Marine Sci. 1969), available at <http://www.vims.edu/GreyLit/VIMS.html>; J.D. Boon & M.P. Lynch, *Tidal Datum Planes and Tidal Boundaries and Their Use as Legal Boundaries: A Study with Recommendations for Virginia*, Special Report in APPLIED MARINE SCIENCE AND OCEAN ENGINEERING, No. 22 (Va. Inst. of Marine Sci. 1972); K. Marcellus, *Coastal Wetlands of Virginia: Interim Report No. 2*, Special Report in APPLIED MARINE SCIENCE AND OCEAN ENGINEERING, No. 27 (Virginia Institute of Marine Science 1972), available at <http://vims.edu/GreyLit/VIMS.html>; J.D. Boon III, M.E. Boule, & G.M. Silberhorn, *Delineation of Tidal Wetlands Boundaries in Lower Chesapeake Bay and Its Tributaries*, Special Report No. 140 in APPLIED MARINE SCIENCE AND OCEAN ENGINEERING (Va. Inst. of Marine Sci. 1977).

140. *E.g.*, Titus, *supra* note 10, at 719.

141. Interview with Hershner & Havens, *supra* note 126.

142. *Id.*

of the sea. So a plethora of bulkheads, sea walls, and revetments were constructed just inside the line of protected wetlands.

This would be harmless enough, if the protected wetlands would only observe the jurisdictional boundary so meticulously set by the legislature. And yet stubbornly, and with apparent total disregard for the hard work of legislators and natural resource managers alike, they did not. Why not? Because, just as stubbornly, sea levels have been rising.¹⁴³ Indeed, the background level of sea rise is approximately one foot per century, but in the Chesapeake region of Virginia, it has risen a foot since 1972.¹⁴⁴

Even that would not be the end of the wetlands, which are designed in nature to accommodate changes in the overall system over time.¹⁴⁵ Unimpeded, wetlands will accrete vertically from the soil level up to accommodate gradual rises in sea-level, which historically rise at the rate of about a foot per century.¹⁴⁶ However, the hardening of the shoreline locks up the seaward movement of sediments necessary to support the natural process of wetland vertical accretion.¹⁴⁷ When shorelines are stabilized this way, it impedes the ability of wetlands to replenish themselves against coastal erosion and rising tides. Worse, there is a limit to how fast marshes can accrete vertically in the face of sea level rise, and the sea level is now rising faster than the wetlands can accrete.¹⁴⁸

Even so, wetlands can also adjust to the rising sea level by migrating laterally upland, maintaining an approximately stable buffer between the aquatic and terrestrial environment.¹⁴⁹ As sea level rises, the water content in soil just upland from the mean high tide level rises, converting to the hydric soil that supports characteristically wetland plant life. The plants already present are able to colonize the new land-side wetland soil even as the vegetation colonizing the tide-side soil is drowned by salt-water

143. *E.g.*, Houck, *supra* note 8 at 14 (noting that sea levels are rising globally this century at a rate of 1.2 mm per year); Titus, *supra* note 10, at 718–19.

144. J.D. BOON, III, SECRETS OF THE TIDE: TIDE AND TIDAL CURRENT ANALYSIS AND APPLICATIONS, STORM SURGES AND SEA LEVEL TRENDS 130 (Horwood Publishing Ltd. 2004); Interview with Hershner & Havens, *supra* note 126.

145. *See* Titus, *supra* note 10, at 718–19.

146. *Id.* *But see* Titus, *supra* note 10, at 718 (stating that global warming could cause the sea level to rise up to two feet per century).

147. *See, e.g.*, Titus, *supra* note 10, at 719.

148. *See* Interview with Hershner & Havens, *supra* note 126.

149. *E.g.*, Titus, *supra* note 10, at 719.

inundation.¹⁵⁰ In this way, the formerly land-side terrestrial boundary becomes part of the wetland, the former tide-side wetland becomes part of the sea, and the wetland barrier that buffers the terrestrial-aquatic boundary is maintained.¹⁵¹ This is how wetlands migrate over the surface of the land over time, and there is evidence of this kind of progression taking place in Virginia a number of times in the geological record.¹⁵²

However, the protected Chesapeake wetlands have nowhere to go now that they are bounded on the upland side by hardened structures like the bulkheads dutifully built on the legal side of the jurisdictional boundary. Now, as sea levels rise, the water level and water table move upland and hit a solid wall. Plants cannot colonize beyond the hardened structure. The water moves upland, saturating and then inundating the wetland soils, drowning the wetland vegetation, and the buffer zone has nowhere to migrate.¹⁵³ It is gradually drowned under the rising sea, and simply disappears.

Dr. Carl Hershner, Director of the Center for Coastal Resources Management at the Virginia Institute of Marine Sciences (“VIMS”), recalls working on the original wetlands protection strategy, and its ironic consequences:

When the Virginia wetland law was passed in 1972, no thought was given to the way that wetlands move over time, or the way that sea level changes over time. Our focus was on how important the wetlands were to the health of the Chesapeake’s waters, not on how they would change over time . . .

At the time, the big battle was with private property owners over new regulation on private lands that abut low water areas. It was only with the “No Net Loss” policies of the 1980s that attention began turning to how wetlands work over time. We weren’t thinking about climate change back then, but the background level of sea level rise began to attract attention in the late 1980s and early 1990s, when landowners began calling the State to report that their wetlands [those beyond the hardened edges of their property] were disappearing. Then we realized that there is a natural cycle of wetland loss and regeneration that follows the cycle of terrestrial-aquatic boundary shift . . .

150. *See generally* WILLIAM J. MITSCH & JAMES G. GOSSELINK, WETLANDS 261–305 (3d ed. 2000) (describing the salt marsh ecosystem).

151. *See id.* at 269.

152. Interview with Hershner & Havens, *supra* note 126.

153. *See, e.g.*, Titus, *supra* note 10, at 726.

We knew to think about the wetlands as ecological service utilities, providing flood control, habitat, and buffering pollution from entering the Bay—but we didn't know to think about their dynamics over time. Now the wetlands that we measured in the 1970s are disappearing into the sea, thanks to the widespread shoreline hardening inspired by our early attempt to protect them.¹⁵⁴

Indeed, between 1993 and 2004, another 229 miles of shoreline were armored with new erosion control structures permitted under the program, approximately equivalent to the length of thirteen Chesapeake Bay Bridge Tunnels laid end to end.¹⁵⁵ (See graphic at Appendix I, page 1026.) Researchers with the Comprehensive Coastal Inventory Program at VIMS have shown that twenty-five percent of the Maryland shoreline has already been hardened in a way that will prevent lateral movement by tidal wetlands.¹⁵⁶

C. *Better Shoreline Stabilization Strategies*

Alarmed by these figures, natural resource managers have scrambled to articulate better programs for shoreline protection that balance the need to protect property against coastal erosion with the importance of preserving healthy connections among sea, wetlands, and uplands and that allow for preservation of the system in the face of geomorphological changes like sea rise and land subsidence.

The result is the “Living Shoreline” model of shoreline stabilization, which promotes natural shoreline systems that can protect themselves against incremental changes in sea level. The Living Shoreline is designed to enable the wetland to remain ecologically connected to both the terrestrial and the aquatic sys-

154. Interview with Hershner & Havens, *supra* note 126.

155. Karen Duhring, *Annual Summary of Permitted Tidal Wetlands Impacts—2004*, 20 THE VIRGINIA WETLANDS REPORT 1 (Va. Inst. of Marine Sci. 2005), available at <http://ccrm.vims.edu/vwr/VWR%202005%20Spring.pdf>; see Appendix I at page 1026, Center for Coastal Resources Management (Va. Inst. of Marine Sci. 2005) (reproduced courtesy of the Center for Coastal Resources Management, Virginia Institute of Marine Science).

156. Letter from Dr. Marcia Berman, Director, Comprehensive Coastal Inventory Program, Va. Inst. of Marine Sci., to author (Nov. 10, 2005) (on file with author) (providing data from forthcoming study indicating twenty-five percent figure); Letter from Dr. Kirk Havens, Assistant Director, Center for Coastal Resources Management, Va. Inst. of Marine Sci., to author (Mar. 16, 2006) (on file with author) (confirming twenty-five percent figure).

tems that maintain them (and which they, in turn, help maintain).¹⁵⁷ (See graphic at Appendix II, page 1027.)

For example, in place of bulkheads and sea walls, the Living Shoreline model advocates use of a relatively new design of shoreline stabilization, the “marsh toe revetment.”¹⁵⁸ A marsh toe revetment is a stone and wood structure positioned between the sea and the marsh (rather than between the marsh and the land, as traditional landward revetments are) that protects against coastal erosion by reflecting wave action back toward the sea, but allows movement of water through the revetment and the marsh, and movement of marsh upland as necessary with sea level rise.¹⁵⁹ (See images at Appendices III and IV, pages 1028–1029.)

The marsh toe revetment thus provides shoreline stabilization services without removing the wetland from the natural systems to which it is tethered. Sea level rise would eventually require repositioning of some structural components, but the design allows for easy reconfiguration, and the wetland is enabled to move with changing conditions. Scientists at VIMS are currently researching the minimum size of an effective marsh toe revetment in various configurations in order to provide building standards that can be easily reproduced by coastal landowners in all circumstances.

The Living Shoreline guarantees neither complete protection for wetlands nor complete protection against coastal erosion, but it is a preferable model over more static traditional stabilization strategies, which guarantee the eventual loss of tidal wetlands and the valuable ecosystem services they provide under conditions of sea level rise. A more ambitious strategy advocated by some coastal resource managers is to couple the Living Shoreline model with a policy of planned “Strategic Retreat,” in which we allow sea level to proceed unmitigated into undeveloped areas and move to protect the wetlands that will be established at the

157. See Tom Barnard, *Preserving the Bay's Living Shorelines: A Growing Grass-Roots Effort*, 19 THE VIRGINIA WETLANDS REPORT 2 (Va. Inst. of Marine Sci. 2004), available at <http://ccrm.vims.edu/vwr/VWR2004Summer.pdf>; Interview with Hershner & Havens, *supra* note 126; see also Appendix II at page 1027 (reproduced courtesy of the Center for Coastal Resources Management, Virginia Institute of Marine Science).

158. Interview with Hershner & Havens, *supra* note 126.

159. *Id.* Photographs of conventional and marsh toe revetments, courtesy of the Center for Coastal Resources Management, Virginia Institute of Marine Science. See Appendices III and IV at pages 1028–29.

new tidal boundary.¹⁶⁰ According to Hershner, we now know enough about sea level rise to predict where marshes are going, or to identify the terrestrial areas that will become valuable salt marshes in the future, so long as the wetland margin is not prevented from moving there by shoreline hardening.¹⁶¹ Hershner proposes that Louisiana purchase such terrestrial lands now, preserve them as state parks, and allow the beaches to go to salt marsh wetlands over time.¹⁶²

D. *Lessons from the Chesapeake: Temporally and Causally Expansive Environmental Assessment*

The Louisiana story betrays the mirage of single-issue natural resource management, suggesting that environmental review be expanded laterally as necessary to account for impacts that might ripple through the distant but joined parts of an ecosystem as broad as the Mississippi watershed and delta lands.¹⁶³ But the Chesapeake natural resource managers had progressed well beyond single-issue management. Their management strategy expressly considered the relationships within the complex regional Bay ecosystem, and sought to prevent undesirable changes (specifically, wetlands degradation) from redounding negatively throughout the rest of the system. However, the unintended consequences wrought in the Chesapeake story suggest that natural resource managers must take even further steps to anticipate how a proposal will reverberate through the complex adaptive ecosystem. In the Chesapeake scenario, it was not enough to simply map the potential impacts of the proposed wetlands policy forward in time; this alone could not have averted the acceleration

160. Interview with Hershner & Havens, *supra* note 126. W.J. Neal, et al., *Managed Retreat*, in M.L. SCHWARTZ, *ENCYCLOPEDIA OF COASTAL SCIENCE* 602-06 (Springer Dordrecht, The Netherlands, 2005). The State of North Carolina follows the planned strategic retreat model. When a coastal storm causes a North Carolina landowner to lose more than fifty percent of her property, that landowner must "retreat," and cannot rebuild structures in the jurisdictional coastal zone. The policy is designed to prevent private and public overinvestment in unmaintainable properties, and to avoid the hazard or marine pollution by overtaking inundated septic systems. See Nat'l Oceanic & Atmospheric Admin., *Social and Demographic Trends that Affect the Need for Beach Nourishment*, <http://www3.csc.noaa.gov/beachnourishment/html/human/socio/change.htm> (last visited Apr. 5, 2006).

161. Interview with Hershner & Havens, *supra* note 126.

162. *Id.*

163. See *supra* Part III.

in wetland loss inadvertently hastened by the policy. To have avoided these unintended consequences, resource managers needed to think outside the box of traditional, forward-looking review. They needed to recognize what other causal factors might intervene in their strategy from the remote corners of the network, and in unanticipated sequences.

Traditional environmental assessment starts from the proposed action and traces all possible impacts forward in time from that action. What degree of attenuation the review must reach remains a point of debate,¹⁶⁴ but the model is uncontroversially linear, and in the forward direction only: review starts with the action and maps out the significant consequences that might flow from that action. The Chesapeake story demonstrates that, in some natural resource contexts, forward linear review is not enough, and that it may also be necessary to perform that causal analysis in the *opposite* direction.

In a complex adaptive system,¹⁶⁵ causal interplay may arise between components in sequences that defy a simple line drawn forward in time. Rather than simply asking what impacts the proposed action might have on other system components, the additional question becomes: what system components might impact *the proposed action*, such as might cause it to backfire?

For example, asking “what impacts might the proposed wetlands regulation have on other system components?” would never have called available data about rising sea level to mind; there is no way in which the wetland protective strategy could be seen as causing sea levels to rise. What was needed was for someone to ask the question, “what will happen under this policy given the incremental rate of sea level rise?” But in contrast to the present day, sea level rise was not a subject of common conversation. Although data detailing background rates of sea level rise were available, no one thought to test the proposed strategy against such data.

What model of assessment might have helped the Chesapeake natural resource managers connect these critical dots, such as

164. For example, the House NEPA Task Forces recommend that attenuation be more limited than it is under current law, H.R. COMM. ON RESOURCES, *supra* note 107, at 28–29. I suggest that the Louisiana story counsels greater attenuation, at least across intervening but related ecosystem processes, *supra* at pp. 19–20.

165. See *supra* notes 13–14.

might have avoided the very wetland loss that their strategy was designed to prevent?

IV. TOWARD A "NETWORK" MODEL OF EXPANDED ENVIRONMENTAL ASSESSMENT

The Chesapeake story illustrates the problem of natural resource planning amidst the complex nature of regional ecosystems, characterized by causal interplay between remote network components that defy linear assessment. What is needed is a model of environmental assessment capable of tracking the network interplay within ecosystems, that would, for example, help the Chesapeake natural resource managers connect the problem of sea level rise to their proposed wetlands protective strategy. Fortunately for natural resource planning, such a model already exists in the realm of consumer products manufacturing.

Natural resource planning could learn from the kind of causally ambidextrous assessment that regularly accompanies the development of such consumer products as automobiles and computer software. When designing a new car, the manufacturer engages in a rigorous assessment of how the vehicle will interact with the world in service of its goal (usually safe transportation). But the manufacturer does not limit its inquiry to the impacts the car will have on the world; it also asks how the world might impact the car. When test models are discovered to react in undesirable ways to foreseeable stimuli (e.g., if the air bag deploys whenever the car taps the bumper of another during parking), their designs are taken back to the drawing board.¹⁶⁶ Though an unlikely source of learning, natural resource planning might stand to benefit from this more causally sophisticated model of assessment. Where traditional environmental review asks: "what about the world might my proposed action 'break'?", causally expanded review adds the critical inquiry: "what in the world might 'break' my proposed action?"

166. This lesson was made especially clear after the famous Ford Pinto case, in which Ford was held liable for its decision to release a car that assessment had revealed would explode upon low impact to the rear bumper. *See Grimshaw v. Ford Motor Co.*, 174 Cal. Rptr. 348, 358-61 (Ct. App. 1981). Ford had based its decision on a cost-benefit analysis that the number of expected deaths did not warrant the expense of the redesign. *See id.* at 384.

A particularly powerful example of this is found in the “quality assurance” practices of the software industry. The quality assurance (“the QA”) stage of software development is the stage at which engineers attempt to rid a new computer program of errors (of the sort we commonly refer to as “bugs”) that may arise when demands are made on the program that may not have been foreseen by its original designers.¹⁶⁷ During the QA stage, a series of engineers attempt to “break” the program by proactively seeking out the circumstances in which the carefully crafted sequences of code stop working as intended.

QA usually proceeds at two levels: (1) “black-box” (or user) testing, and (2) “white-box” (or programmer) testing.¹⁶⁸ In black-box testing, an analyst follows the directions in a carefully prepared *use case*, which instructs the analyst to test the program as though she is an anticipated user.¹⁶⁹ For example, an analyst testing recruiting software might follow the prompts of a use case that tells her she is a job applicant trying to upload her resume, and asks her to find out what would happen if the resume she uploads is blank, is 100 pages long, is in a foreign language, or has command characters embedded in the text, etc. When the black-box tester performs an action that causes the program to seize or otherwise misperform, she then sends the problem to the white-box analyst who examines the actual code for errors that might be responsible. Together, QA analysts try to “break” the program, in order to anticipate and resolve any programming errors or oversights that might compromise the performance of the software in the real world.¹⁷⁰

The Chesapeake story demonstrates how natural resource managers might learn from software programmers, by including an additional step in environmental review by which they run the linear causal assessment *backward* as well as forward, asking not only what external factors might be upset by a proposed resource management strategy, but also what external factors might upset the strategy itself. In natural resource management “quality assurance,” the planners would consider a proposed strategy from

167. See generally GLENFORD J. MEYERS, *THE ART OF SOFTWARE TESTING* (1979); G. GORDON SCHULMEYER & JAMES I. MCMANUS, *THE HANDBOOK OF SOFTWARE QUALITY ASSURANCE* (3d ed. 1999).

168. See, e.g., MEYERS, *supra* note 167, at 8–11.

169. See generally WRITING EFFECTIVE USE CASES (Alistair Cockburn ed., 2001).

170. See MEYERS, *supra* 167, at 18–20.

multiple vantage points in the network, asking “what factors or events could cause our plan to fail?” Tempered by a risk analysis (allocating attention to such factors according to their likelihood and potential magnitude)¹⁷¹ and an outer boundary of proximate causation,¹⁷² resource managers would brainstorm causal connections back and forth across the proposed plan, seeking any points of friction that deserve further inquiry.

According to this technique, a natural resource planner confronting the Chesapeake wetlands policy would proceed as follows. As in traditional review, the first step would be to isolate the goal and purposes intended by the management strategy:

Our goal is to protect wetland services provided by the tidal wetlands that ring the Chesapeake. Our plan is to accomplish this by protecting wetlands at an elevation of one and one-half times the mean high tide from structural development that might compromise service provision. This should ensure a stable margin of wetlands sufficient to provide habitat, water purification, and flood control. Hardening the barrier beyond this protected margin should be acceptable, because the amount of wetland protected is sufficient to provide the needed services.

After making the important inquiries of traditional linear review, the planner's next step is to consider external factors that might cause the plan itself to backfire. The planner might ask whether anticipated hardening landward of the jurisdictional line might somehow compromise the health of the protected wetlands seaward of the line, and determine whether this inquiry deserves further consideration. Similarly, the planner might consider whether enforcement issues are likely to complicate success of the plan, or whether the likelihood of increased agricultural run-off might warrant adjustment of the jurisdictional line. And, at some point in the process of considering what might sideline the goals of the strategy, we might imagine our planner's thought process to run as follows:

171. This is risk analysis of the traditional Learned Hand formula variety, where the burden of preventing a harm is the product of the probability of its occurrence and the magnitude of its potential harm. *United States v. Carroll Towing Co.*, 159 F.2d 169, 173 (2d Cir. 1947). By this technique, the impact of extraterrestrial invasion on wetlands protection, coupled with a fast risk analysis, might prove unworthy of further consideration—but the impact of possible sea level rise, given the data available in the 1970s, would still warrant attention.

172. *See, e.g.*, *Babbitt v. Sweet Home Chapter of Cmty. for a Great Or.*, 515 U.S. 687, 709 (1995) (O'Connor, J., concurring).

Come to think of it, everything in this strategy is tied to the elevation of the protected wetlands above sea level. If sea level were to change, this would change the amount of wetlands protected. If sea level were to lower, then more wetlands would be protected. For example, if we enter another ice age, sea level will fall as water is locked into expanding polar glaciers, and we might have more wetlands (if they are not covered by continental ice). But if sea level rises, fewer wetlands will be protected, and the barrier will act as an impermeable boundary above which wetlands cannot move over time as they naturally do. If sea level rises, then, the plan is likely to fail. So what is the chance of that happening? Many features in the geologic record tell us that sea level is not static over time, but which way is it likely to go, and over what kind of time horizon are changes likely to happen? This is something we should probably look into a bit further.

Having isolated the potential problem, the planner then engages in the risk analysis. She will ask how likely is it that sea level will rise or fall. If she does not know, she will seek more information: “How much data do we have about sea level rise?”; “What do we know about the likelihood of sea level rise over our time horizon?”; then, if not already established, “What is a reasonable time horizon for this strategy?”; and “Are there any foreseeable factors that might cause additional sea level rise in this time horizon?”

Even in the 1970s, before climate change became an issue, scientists had charted a background rate of sea level rise over the past century.¹⁷³ In other words, data about sea level rise were there all along, but nobody had thought to ask about the data. Linear environmental assessment alone would not have uncovered the significance of this looming threat to the management strategy. Even the “worst case scenario” inquiry at the limit of NEPA assessment is essentially a linear inquiry, asking only about the worst possible impacts *arising from* the proposed government action, and not about the worst case scenario in which the proposed action might play a supporting role. Only a more flexible inquiry that reversed the forward causal path could have directed the natural resource managers’ attention to this latent flaw in the plan—and might have made the difference between the Bay’s recovery from the dead zone, and its condemnation to expanded anoxia.

173. See Titus, *supra* note 125, at 1297–1300, fig.4.

It is important to note that there is nothing especially groundbreaking about this kind of causally expanded analysis; it is not only commonplace in the consumer goods quality assurance process, but it is also the strategy of weighing possibilities that most of us reflexively use whenever we make important decisions about choices between alternatives. When we consider which job to take, which place to live, whether or not to commit, or how best to accomplish a goal, we hardly start from the proposed action and trace consequences blindly forward in time! Rather, we ponder the various factors within the relevant network that bear on the decision, the various “what ifs” that ultimately help us evaluate the choice: “What if I receive the other job offer next week?”, or “How would this basement fare in a flood?”

Causally expanded, network-based assessment is thus the bread and butter of ordinary good decision making—and yet it is not among the obligations of traditional environmental review. Perhaps the time has come that it should be. To the extent that multidirectional causal analysis duplicates existing patterns of assessment, it puts no additional burden on natural resource planning. But to the extent it compels a critical chain of inquiry that might otherwise be missed, it might prove the difference between a successful natural resource management strategy and a catastrophic collision with the law of unintended consequences—for example, the accidental loss of the very Chesapeake wetlands designated for protection.

The Chesapeake story is a powerful cautionary tale, highlighting the problem of the limits of conventional environment assessment. How much protection does linear environmental assessment really afford? On the other hand, causally expanded network assessment poses new problems. How far down the line of causation must we look, and how many lines should we follow? Demonstrating that we should ask more assessment questions than we currently do is one thing, but under the network model, how will we know when we have asked *enough* questions? Network assessment threatens to overwhelm natural resource management decision making without a decision rule for knowing when you have reached the end of the assessment.

This is a formidable problem, and yet one that is familiar within the architecture of the common law. In particular, the doctrine of proximate causation has evolved as a means of constraining the potentially limitless duty of care that we owe to prevent

foreseeable harms under the principles of tort law.¹⁷⁴ If a harm is not reasonably foreseeable, no one can be held responsible for failing to avoid it. At a certain point of attenuation into the future, even the most knowledgeable earth scientist cannot forecast how events will unfold, especially within the complex adaptive networks of regional ecosystems.¹⁷⁵ Putting the model into practice will enable the articulation of a more refined decision rule for completion; in the meanwhile, we can rely on the familiar vocabulary of proximate causation as a means of establishing the boundaries of causally expanded assessment.

However, a primary objection to the suggestion that we experiment with additional assessment obligations is that environmental assessment *already* consumes scarce time and financial resources at a sobering rate. Indeed, we should not be quick to add to the imposition that has already led to the backlash against NEPA in the House of Representatives. This is a serious concern that deserves careful scrutiny before any model of network assessment—here only thinly sketched out—becomes formal policy.

Nevertheless, Virginia's natural resource law provides a solid example of how to impose additional review requirements in the least onerous way via the Chesapeake Bay Preservation Act,¹⁷⁶ which successfully imposed new obligations to minimize phosphorous load increases associated with coastal development on top of an already onerous array of assessment requirements. The new regulations require that all development in the resource protection area be assessed for any changes in phosphorous loading, and that best management practices be adopted as necessary to bring the phosphorous load back to the pre-project baseline.¹⁷⁷ The regulations are onerous as a facial matter, but they are accompanied by exhaustive guidance for performing the required tasks at every step, making the process much more straightforward (and thus palatable) to regulated parties.¹⁷⁸

174. See, e.g., *Babbitt*, 515 U.S. at 687, 709–13 (O'Connor, J., concurring).

175. Still, the baseline for causation in natural resource planning should be defined not according to the generic "reasonable person standard" but the "reasonable earth-scientist standard" of foreseeability. Earth science teaches us, and Katrina reminded us, of the importance of heeding even attenuated causality across ecosystem function.

176. VA. CODE ANN. § 10.1-2100 to -2116 (2005).

177. See 9 VA. ADMIN. CODE § 10-20-120(9) (2004).

178. Interview with Carl Hershner, Dir., Ctr. for Coastal Res. Mgmt., Va. Inst. of Marine Sci., in Gloucester, Va. (Jan. 23, 2006).

Natural resource managers' experience with the Chesapeake Bay Preservation Act indicates that the best way to impose additional assessment requirements on natural resource planning is to make them as easy as possible to follow, by accompanying such requirements or suggested best practices with technical guidance that leads the planner from one step of the process to the next. Were planners asked or encouraged to cap traditional assessment with a causally expanded network-based inquiry, it might be wise to make available a list of questions that planners should consider in each realm of resource management—a stylized decision-tree of inquiry for proposed actions relating to water, air, land, or biodiversity resources, coupled with more specific decision-trees within such categories—a veritable “use case” for natural resource planning.

In this respect, asking natural resource planning to depart from the linear model of review further tracks the development of computer science, which has progressed from the linear to the “object-oriented” programming model. Linear programs can proceed in only one direction, while object-oriented programs are structured to enable freer and more efficient movement between networked categories of operations, connected in “parallel” rather than “series” formation. In contrast to the linear model of environmental review, a more “object-oriented” environmental review might be conceptualized as a network model of review. Like a network of communication lines, roads, or neurons, the network approach to assessment encourages the planner to trace potential causal connections along the circuitous routes that bridge the proposed management strategy to the external environment in which it would play a role. Network assessment would encourage more facile consideration of impacts that arise over attenuated branches of a complex ecosystem (as between the Mississippi River and coastal land loss in Louisiana), and a more ambidextrously causal analysis of the relationship between the strategy, the environmental factors it might “break,” and the environmental factors that might “break” it—leading to unintended consequences.

Of course, expanded assessment responsibilities will consume additional resources, no matter how well-accompanied by technical guidance (although this should rightly be viewed as an investment in preventing more costly unintended consequences). Moreover, we will need to better define the end-point of causally

expanded assessment, to ensure the benefits of more sophisticated review are not outweighed by the needless costs of overly speculative review. Finally, even a sophisticated policy of natural resource management QA cannot foresee every potential consequence, nor is risk analysis a guarantee that tiny risks will not materialize into catastrophes.¹⁷⁹ As a certain matter of probability, they occasionally will. But perfection should not be the enemy of the good. A category five storm on the Gulf Coast was not an unforeseeable or even an unlikely risk, as recognized by increasingly alarmed Louisiana leaders in recent discussions about restructuring management of the Mississippi.¹⁸⁰ Nor was sea-level rise wholly unforeseeable in Virginia in the 1970s, based on historic incremental measurements along the Chesapeake coastline (if not on global warming concerns). If we cannot engage in perfect natural resource management, we can at least do better.

V. CONCLUSION

As our ability to manipulate the environment outpaces our ability to understand it, the need to move toward more sophisticated models of natural resource planning and environmental assessment becomes pronounced. The devastating tales of the post-Katrina flooding of New Orleans and the loss of protected Chesapeake wetlands demonstrate the dilemma of unintended consequences of natural resource management—but they also offer counsel on how to avoid them in the future.

Taken together, the Louisiana and Chesapeake stories suggest three lessons for natural resource management. First, policy makers must consider the full extent of lateral ecosystem interconnectedness when intervening in such complex natural systems as alluvial rivers or shorelines. Second, they must give special consideration to the ways that regional ecosystems change over time—both over geologic time, and in light of the more accelerated changes that accompany foreseeably abrupt natural or anthropogenic transitions, such as climate change.

179. For example, the threat of a planetary asteroid collision that was temporarily projected for 2029 has receded into the realm of the improbable, but not the impossible. See Guy Gugliotta, *A New Path for Asteroids: A Craft's Gravity Could Protect Earth*, WASH. POST, Nov. 10, 2005, at A3; see also Alan Boyle, *Astronomers Rule Out Asteroid Risk in 2029: Further Observations Show Space Rock Won't Hit Earth*, <http://www.msnbc.msn.com/id/6751433/> (last visited Apr. 5, 2006).

180. *E.g.*, Brancaccio, *supra* note 35 (noting comments by Daniel Zwerdling).

Finally, natural resource planners must expand assessment practices from the traditional linear model, which considers only the significance of impacts that flow forward from the proposed project, toward a causally expanded model that also considers how network components might intervene to impact the proposed strategy. Such a network-based model would not only facilitate laterally and temporally expansive ecosystemic assessment, but also the consideration of causal interplay between the proposal and network factors that might ultimately undermine its ultimate goals. That we could not possibly have foreseen unintended consequence using linear assessment is a passable excuse only once.

It is ironic—and disquieting—that our two cautionary tales herald the importance of better natural resource planning at the very time that Congress is considering recommendations to relax existing requirements for environmental review under NEPA.¹⁸¹ There may well be ways to improve upon the administrative baseline set by NEPA, but changes that would weaken the quality of long-range environmental assessment threaten our ability to forestall potential devastation of the sort experienced in New Orleans and feared in Virginia. Now more than ever, natural resource planning must become more, not less, ambitious.

Nevertheless, NEPA, critical though it is, defines the floor, not the ceiling of natural resource planning. Policy makers and resource managers should respect the assessment floor mandated by state and federal natural resources law, and aspire to a more powerful model of network-based assessment that will foster more robust environmental policies that better anticipate the causal interplay within complex regional ecosystems.

Future advocacy for expanded assessment must contend with the serious issues of increased costs and uncertain limits associated with expanded obligations at a time when existing assessment requirements are burdensome to smaller planning agencies.

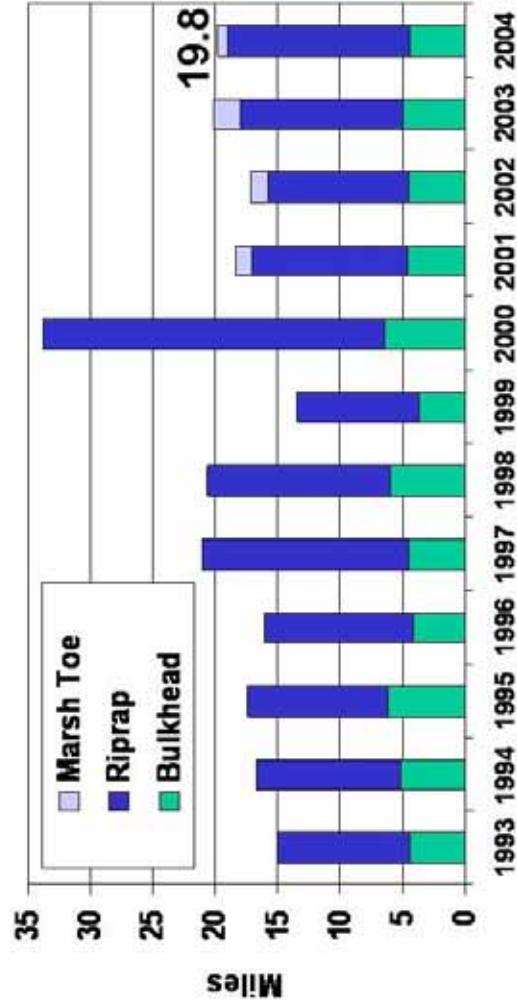
181. 42 U.S.C. § 4321 (2000). The United States House of Representatives Committee on Resources is considering recommendations by its NEPA Task Forces to amend NEPA in ways that might strengthen mitigation requirements but would expand exemptions and weaken the requirements for environmental assessment. *See* H.R. COMM. ON RES., 109TH CONG., TASK FORCE ON IMPROVING THE NATIONAL ENVIRONMENTAL POLICY ACT AND TASK FORCE ON UPDATING THE NATIONAL ENVIRONMENTAL POLICY ACT, INITIAL FINDINGS AND RECOMMENDATIONS, 25–29 (Dec. 21, 2005), *available at* http://resourcescommittee.house.gov/nepataskforce/report/nepareport_finaldraft.pdf.

However, the transition to network-assessment best practices could be aided by the development of detailed technical guidance to lead planners from one step of the process to the next, a realm in which future work is sorely needed. In addition, planners could gradually adapt the expanded network model into existing assessment practices by limiting the scale of proposal for which network assessment is appropriate, beginning with only the largest or programmatic assessment endeavors and gradually introducing the techniques for smaller projects as the process becomes more streamlined. In the end, a move toward network assessment will prove an investment well worth the initial costs when it helps us avoid the more costly wrath of the Law of Unintended Consequences.

Assessment of this kind is hardly without precedent. Not only does it represent the sort of careful evaluation that individuals routinely apply in the sphere of private decision-making, but network-oriented models are also available among the assessment practices of consumer products manufacturers, such as automobile and software testing. It may be that the more careful assessment associated with consumer products is the result of the strict liability regime in which this market is situated—but this is all the more reason for natural resource managers to take heed of their methods. After all, natural resource management is ultimately a strict liability affair as well. The Natural Resources Law of Unintended Consequences mitigates damages neither for good faith nor complex causation. And unfortunately, when our natural resources and the services they provide are damaged, we all bear the loss.

Appendix I

NEW SHORELINE STRUCTURES

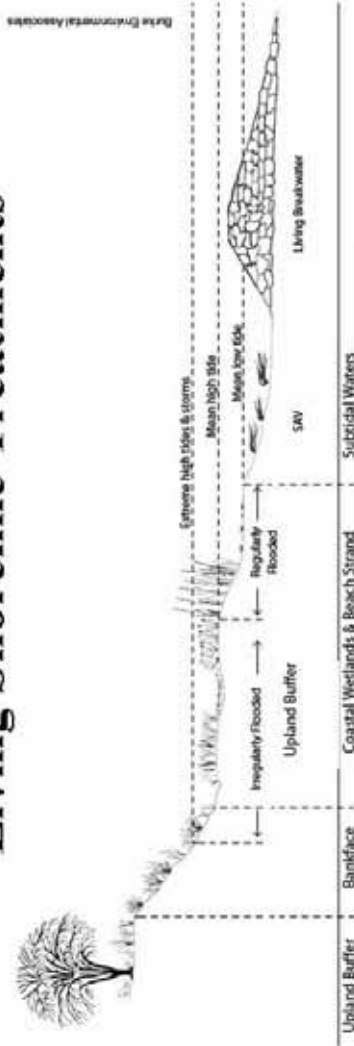


Total Miles New Shoreline Hardening (1993-2004)

Reproduced courtesy of the Center for Coastal Resource Management, Virginia Institute of Marine Sciences

Appendix II

Living Shoreline Treatments



Native Trees in Upland Buffer

Deep Rooted Native Grasses & Shrubs on Banks

Wetland Plants Matched to Tidal Hydrology & Salinity
Sills, Stone Surface Groins, Marsh Toe Revetments, Marshy Islands

Submerged Aquatic Vegetation
Artificial Oyster Reefs

Reproduced courtesy of the Center for Coastal Resource Management, Virginia Institute of Marine Sciences

Appendix III



Conventional Revetment
Reproduced courtesy of the Center for Coastal Resource Management, Virginia Institute of Marine Sciences

Appendix IV



Marsh Toe Revetment

Reproduced courtesy of the Center for Coastal Resource Management, Virginia Institute of Marine Sciences