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Disaster and Response in an Experiment Called New Orleans, 1700s–2000s

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Summary and Keywords

As an urbanized river-dominated delta, New Orleans, Louisiana, ranks among the most experimental of cities, a test of whether the needs of a stable human settlement can coexist with the fluidity of a deltaic environment—and what happens when they do not.

That natural environment bestowed upon New Orleans numerous advantages, among them abundant fresh water, fertile soils, productive wetlands and, above all, expedient passage between maritime and continental realms. But with those advantages came exposure to potential hazards—an overflowing Mississippi River, a tempestuous Gulf of Mexico, sinking soils, eroding coasts, rising seas, biotic invasion, pestilence, political and racial discord, conflagration—made all the worse by the high levels of social vulnerability borne by all too many members of New Orleans' population. More so than any other major metropolis on the North American continent, this history of disaster and response is about the future of New Orleans as much as it is about the past.

This article examines two dozen disasters of various types and scales, with origins oftentimes traceable to anthropogenic manipulation of the natural environment, and assesses the nature of New Orleans' responses. It frames these assessments in the "risk triangle" framework offered by David Crichton and other researchers, which views urban risk as a function of hazard, exposure, and vulnerability. "Hazard" implies the disastrous event or trauma itself; "exposure" means human proximity to the hazard, usually in the form of settlement patterns, and "vulnerability" indicates individuals' and communities' ability to respond resiliently and adaptively—which itself is a function of education, income, age, race, language, social capital, and other factors—after having been exposed to a hazard.

Keywords: New Orleans, Louisiana, flooding, disaster, recovery, adaptation, resilience, hurricanes, Mississippi River, delta cities

A Delta Forms—and Progrades

While epidemiological disasters have by far killed the most New Orleanians, it is the hazard of inundation that has threatened New Orleans at the most existential levels. This was the case in the early 1700s and, for different reasons, in the 2000s as well. Key to understanding why this is so requires an understanding of New Orleans' distinctively youthful and fluid physical geography.

Prehistorically, what is now southern Louisiana alternated between terrestrial and aquatic states as sea levels fluctuated with global climate change. After glacial maximum (approximately eighteen thousand years ago), ice sheets covering half of North America once again receded, releasing vast volumes of sediment-laden runoff down the tributaries and main channel of the Mississippi River.

There they entered into the Mississippi Embayment, a down-warping of the Earth's crust situated between present-day Cairo, Illinois, and Natchez, Mississippi, with Memphis on its east flank and Little Rock to the west. Because sea level continued to rise, the river gradient weakened, water velocity slowed, and alluvium settled to the bed, sedimenting the embayment with a marshy landscape of braided channels. Adjacent bluffs and terraces constrained the flow of water to within a broad meander belt, forming the bottomlands of the present-day states of Arkansas, Tennessee, Mississippi, and Louisiana —the lower Mississippi River alluvial valley.

That meager topography petered out south of present-day Baton Rouge, where, as recently as seven thousand years ago, the Mississippi disembogued into the Gulf of Mexico. It deposited its sediment load upon a seafloor of hard compacted clay, to the point that the accumulation broke the sea surface, forming saline marshes laced with ridges. Because of its immense water volume and sediment load, the river largely overpowered the relatively weak tides and longshore currents of the Gulf of Mexico and extended its depositions outwardly. It helped that global warming diminished somewhat in these millennia, giving a chance for sediment consolidation to outpace the slackened rise in the level of the sea.

Occasionally a weak spot in the Mississippi's bank would develop into a crevasse (breach) and allow a trickle of water to flow outwardly. Some would grow into permanent "distributaries," such as Bayou Manchac and Bayou Lafourche. If the gradient of the new outflow proved steeper than that of the main channel, the entire water column might lunge in the new direction (avulsion), an event that occurred at a pace of roughly once per millennium. The new channel would instigate land building in yet another area. In this manner, the shifting, jumping mouths of the Mississippi River prograded farther and wider into the Gulf of Mexico, creating a network of active and abandoned deltaic complexes—a deltaic plain—which would eventually become southeastern Louisiana and home to New Orleans.

Delta-building occurred also along the river's flanks. Springtime overflows spread a thin sheet of excess water laterally across the plain, enriching swamp and marsh ecosystems by pushing back salt water and depositing new sediment. Fine sand and silt particles settled in the largest quantities closest to the river, building up those areas highest (natural levees), while fine clay particles settled in lesser quantities farthest away in the backswamp, where they mixed with organic matter and standing water. Thus, by the time European eyes first saw them, the natural levees had risen three to five meters (about ten to sixteen feet) above sea level, and usually one to two meters (three to six feet) above mean river stage, while the backswamp sat only a dozen centimeters (less than five inches) or so above the brackish tidal lagoon named Lake Pontchartrain. These lands were not, however, below the level of the sea until anthropogenic actions allowed them to subside, thus laying the groundwork for modern New Orleans' increasing exposure to hazard.

The processes that created the Mississippi River deltaic plain are distinctive for their sheer magnitude. Most rivers do not form deltas at all but only estuaries—admixtures of fresh and salt water—as they discharge into the sea. New York's Hudson River is one such example: it lacks the sediment load to create a delta. Even larger sediment-bearing rivers are still usually at the mercy of wave or tidal action in shaping their alluvial deposits, which typically protrude only modestly from the coastline, in the triangular form of the Greek letter Δ (hence the name). Others play out within a system of internal bays protected by straits and peninsulas, such as the Senegal and Sacramento river deltas, while others blend smoothly with adjacent coastal bights, such as in the Netherlands, as ocean dynamics sweep away most of what gets deposited. River-dominated (or fluvial) deltas, on the other hand, occur when rivers bear enough water and sediment to overpower the sea's actions, enabling the channel to meander, jump, send off distributaries, and build land faster than waves or tides can sweep it away. The resulting formations prograde into the receiving water body, often with multiple lobes spanning broadly. The Mississippi Delta ranks as one of the world's best examples of a major river-dominated delta, and New Orleans rates as a premier experiment in delta urbanism.

Humanizing the Delta: Native and Colonial Approaches

Rich alluvial soils and a subtropical climate fostered verdant flora and abundant fauna, and for this reason as well as access, natives occupied the deltaic plain in substantial numbers; it was hardly the "forest primeval" of the European-American imagination. Indigenous peoples negotiated the watery semi-earth by shoring up elevations through middens and other anthropogenic topography, or adapting to the environment by shifting to higher ground when high water came. Given their technological limitations, natives viewed deltas as conditions to which one must adapt, rather than problems in need of fixing.

Such a strategy aligns with the needs of semi-nomadic hunter-gatherer societies. It does not, however, serve the aims of agricultural and resource extraction–based societies seeking to expand hinterland-foreland domains and establish mercantilist nodes. For these societies, "soft" deltaic fluidity represented an intolerable problem which demanded a solution, and their tool of choice was the one feature utterly absent in deltas: the "hard line," as manifested in levees, walls, weirs, barriers, and canals.

These devices became necessary when French colonials under the command of Jean Baptiste Le Moyne, sieur de Bienville established New Orleans in 1718 in the heart of this active delta, roughly 150 kilometers (93 miles) above the river's mouth. Their motivations were both commercial and imperial, thus their reconnaissance and site-selection decisions were weighed for economic as well as geographical and political advantages. While the selected *site* for New Orleans (low in elevation, high in soil water, inundated regularly by the Mississippi, and prone to tropical storms) appeared precarious, its geographical *situation* (that is, how it connected with the rest of the world) seemed enticingly strategic. A city near the mouth of North America's greatest river positioned French colonials to defend and exploit the unknown riches of the vast Mississippi Valley from Spanish and English interests. Other potential sites were either more precarious or less strategic. Should New Orleans be built on the safest site, despite its inconvenience? Or should it exploit the most strategic situation, despite its hazards? French authorities opted for the latter, setting the stage for three centuries of blessings and curses.

Colonial Times

The 1719 Flood

Barely a year after its establishment, New Orleans experienced its first disaster. In the spring of 1719, high waters on the Mississippi inundated the muddy outpost, delighting colonials in the competing French settlements of Natchez, Biloxi, and Mobile who saw New Orleans' ascent as coming at their expense. The incident caused Bienville's superiors to shift attention to New Biloxi, which they soon designated as company headquarters. But New Orleans' superior geographical situation (if not site), plus Bienville's advocacy and the engineering of Adrian de Pauger, eventually won over company officials, and on December 23, 1721, they designated New Orleans as capital and headquarters of the colony. The nascent city rebounded with a company store, hospital, houses for the governor and director, over 100 employees, and 250 concession-holders ready to take possession of their land.

If there were any one response to the 1719 flood, it came in the form of rudimentary artificial levees (*lever*, to raise up) built atop the crest of the natural levees. These were followed by more organized efforts during 1722–1723, when engineers Le Blond de La Tour and Adrien de Pauger planned an earthen embankment about 4 meters (13 feet) wide reinforced with a double palisade of timbers. By 1724, this first levee measured 2 meters (6 feet) wide, 1,000 meters (3,300 feet) long, and one meter (13 feet) high, but was readily breached by the high waters of the Mississippi that spring. The ensuing reconstruction and reinforcement work was constantly hampered by a meager workforce; nevertheless, by 1727, a solid six-meter-wide (twenty foot), one-meter-high (three foot) dyke, plus a parallel ditch to collect seepage, lined 1.5 kilometers (nearly one mile) of the town's riverfront. The devices mark New Orleans' first organized attempt to reduce its exposure to hazard.

The 1722 Hurricane

Unlike the nearby outpost of Mobile, urbanization in New Orleans began without the initial surveying of a street grid. But nor was it completely indiscriminate. Probably with the collaboration of Mobile planner Jacques Barbizon de Pailloux, Bienville laid out an angled baseline running about 200 meters (over 650 feet) from the river, which today would run between, and parallel to, Charters and Royal streets. The line faced approaching river traffic, as if Bienville expected a fortified plat to be forthcoming. In the meantime, residents began building shelters in a desultory fashion. One observer described the outpost as comprising "about a hundred forty barracks, disposed with no great regularity, [plus] a few inconsiderable houses, scattered up and down, without any order . . . *New Orleans*, in 1720, made a very contemptible figure . . ."

That "contemptible" disorder flummoxed Adrien de Pauger, the assistant engineer tasked to design and deploy an orderly grid. Pauger explored the terrain, analyzed its topography and soils, and observed its spatial relationships. Sensing that conformity to the Bienville-Pailloux line would be needlessly conservative, he decided to move his plat closer to the river, to today's Decatur Street. Pauger explained "the changes I have been obliged to make because of the situation of the terrain, which being higher on the river bank, I have brought the town site . . . closer to it, so as to profit from the proximity of the landing place as well as to have more air from the breezes that come from it."

It was a wise move. Pauger's shift gave the city close to a meter of added topographic elevation, enough to reduce its exposure to water rising in the backswamp—the likes of which would flood the city in 1816, 1849, 1871, and 2005. As for riverfront space, plenty remained for shipping activity, and there would be yet more when, decades later, the river fortuitously deposited a sandy beach (*batture*) between the levee and channel. This is today's upper French Quarter riverfront and Warehouse District.

What frustrated Pauger's plan, however, were the extant houses scattered indiscriminately. "Pauger . . . has just shown me a plan of his own invention;" wrote a local observer, "but it will not be so easy to put into execution, as it has been to draw . . ." Indeed, Pauger nearly got into fisticuffs with neighbors who resisted his call to clear the way, and went so far as to produce a map illustrating the conflicts.

Nature resolved the conflict. On September 11, 1722, "a great wind" swept the settlement, "followed an hour later by the most terrible tempest and hurricane," recalled Pauger. "With this impetuous wind came such torrents of rain," wrote another eyewitness, "that you could not step out a moment without risk of being drowned[;] it rooted up the largest trees, and the birds, unable to keep up, fell in the streets."

The first hurricane to strike the newly formed city of New Orleans destroyed or damaged thirty-four houses plus ships, cargo, and infrastructure. Yet, reflecting the axiom than one's disaster is another's opportunity, the storm gave Pauger a chance to move forward with his plan. "All these buildings were old and provisionally built, and not a single one in the alignment of the new city," he wrote, "and thus would have had to be demolished. Thus there would not have been any great misfortune in this disaster except that we must act to put all the people in shelter." Less than two months later, blocks were surveyed, parcels delineated, and "the streets of the old quarter had received the names they still bear." It was in 1722, according to Dumont, that "New Orleans began to assume the appearance of a city."

The hurricane of 1722 figuratively "wiped the slate clean" because the four prior years of place-making proved too brief for residents to inscribe economic or psychological value into the deltaic space, and the promise of a better city trumped reverting to the one destroyed. Contrast this with the experience after Hurricane Katrina (2005), by which time nearly three hundred years of prior investment had created a vast reservoir of place-based value; the floodwaters, despite their destructiveness, by no means "wiped the slate clean," and the populace largely rejected radical change in favor of returning to prior form. If "resilience benefits from the inertia of prior investments," then radical change may well be enabled by *minimal* prior investment. This was the case in New Orleans after the 1719 flood and the 1722 hurricane: there was so little invested in what was lost that bold new plans—for new flood control and orderly urban planning—were able to move forward in the aftermath. (It helped, of course, that New Orleans society at the time was not a democracy; it was a colonial project of a private company backed by an absolutist monarchy.)

That monarchy lost nearly all its New World colonies after its defeat in the French and Indian (Seven Years') War. Portions of former New France went to the British, while Louisiana and New Orleans transferred in the late 1760s to the Spanish. The populace, however, generally retained its creolized Francophone Caribbean culture, and many administrators sent from Spain married into the Creole elite. French predominated linguistically; only official documents and discourse were regularly in Spanish. The 1778 census enumerated 3,059 people living on the "68 isles [blocks] which form the City of New Orleans," of whom 51 percent were "whites;" 8 percent were described as "free, of mixed blood;" 3 percent "free negroes;" 7 percent "slaves, mixed blood;" and at the bottom of the social pyramid, "negro slaves," 31 percent.

The 1788 Fire

The next fifteen years would be riddled with disasters. Tropical storms struck in 1776, twice in 1779, and in 1780, 1781, 1793, and 1794. But the most destructive traumas were incendiary, and the worst in the city's history came on the breezy Good Friday of 1788, A woman had left a votive burning at a home at Chartres and Toulouse, and "during her absence," wrote a contemporary, "a candle fell . . . and the house in an instant was in flames . . ." By late afternoon, "4/5 of the populated section of this City was reduced to ashes, [including] the Parish Church and House, Cabildo [city hall] and Jail . . ." Worse yet, the charred area comprised "the part of the City most important and best situated." At least twenty squares were reduced to ashes, and 856 "fine and commodious houses valued on an average at three thousand dollars each, were destroyed," including most of the aging French-era buildings, with their cross-timbered walls and double-pitched hip roofs. Roughly 80 percent of the city lay in utter ruin (Figure 1), a higher proportion and a greater intensity of destruction than brought about by Hurricane Katrina.

Yet New Orleans proved resilient in the aftermath, thanks to the leadership of Governor Miro, the Cabildo's provisioning of food and shelter, the fiscal generosity of private benefactor Don Andres Almonester y Roxas, the easing of trade regulations, and a construction boom in the city's first *suburbia*, Santa Maria (today's Central Business District). This expansion came in direct response to the ruinous blaze, exactly the opposite of the circa-2005 attempt to "shrink the urban footprint" in the wake of the Katrina deluge.

Although hundreds of French colonial structures disappeared in the blaze, the French West Indian architectural tradition persisted, and the new wooden houses that gradually arose in the fire zone generally exhibited the same designs of earlier decades. The Spanish response to the disaster focused on fire suppression rather than prevention, as they requested from their superiors "four pumps . . . 60 leather buckets . . . two hooks with a chain . . . rope . . . and six hooks with long wooden handles."

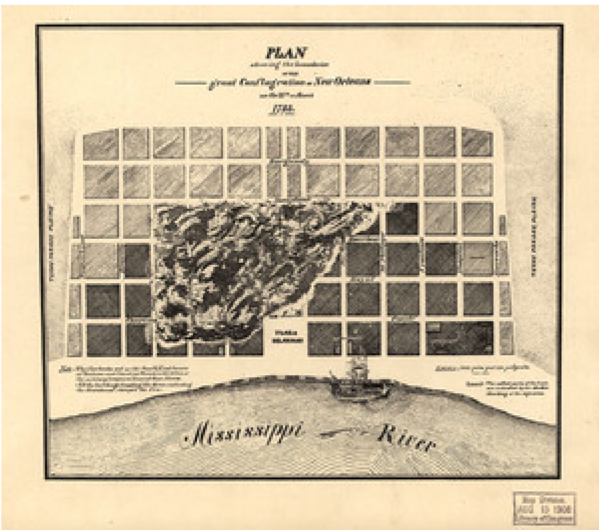

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Figure 1: "Plan showing the boundaries of the great conflagration of New Orleans on the 21st of March 1788."

Courtesy of Library of Congress, Geography and Map Division.

The 1794 Fire

Six years later, on December 8, 1794, boys playing in a Royal Street courtyard ignited flames which swept southwardly with autumn winds. Within three hours the fire "reduced to ashes one third of the . . . Capital city . . ." The "dreadful conflagration" destroyed 212 structures, once again throughout "the most improved and opulent part of that city."

Unlike in 1788, however, this time the Cabildo responded by aiming not only to suppress but also to prevent future fires, by reducing hazards and looking to their own building traditions to codify a more fire-resistant cityscape. It stipulated that new houses funded with the king's loan "must be built of bricks and a flat roof or tile roof," and that "two story houses . . . should all be constructed of brick or lumber filled with brick between the upright posts, the posts to be covered with cement of at least one inch thick, covered with a flat roof of tile or brick." Authorities further stipulated "that the wooden houses covered with the same material must not be of more than 30 feet deep[;] that all houses . . . must precisely have their front facing the street, and nobody is allowed to build them with the rear or sides to the street . . ." Extant houses had to be strengthened "to stand a roof of fire-proof materials," their wooden beams "covered with . . . fire-proof material," namely cement (stucco). "[All] citizens must comply with these rules whenever they wish to construct a new building," concluded the Cabildo.

It is difficult to evaluate the efficacy of the Spanish architecture code, given the change of dominion to the United Stated after the Louisiana Purchase (1803) and the subsequent rapid urban grown. But there were no additional great urban conflagrations for a century to come. As for climatological disasters in this era, significant tropical storms struck New Orleans at least seven times during the antebellum era (1803–1861)—in 1812, 1821, twice in 1831, 1837, 1856, and 1860—and left behind ample wind damage but limited water destruction due to the buffering effects of vast and healthy deltaic wetlands. Greater hazard came from epidemiological and riverine sources, and at least potentially, from military foes.

The 19th Century

The 1815 Disaster Averted

A decade after Americanization and three years after statehood (1812), New Orleans found itself targeted by the British military as an ingress into the vulnerable underbelly of the United States. The Gulf Coast presented a third theater in the War of 1812, after British forces had been repelled from Lake Champlain and the Chesapeake but subsequently gained reinforcements after the 1814 defeat of Napoleon. In December of that year, five thousand professional British soldiers approached lower New Orleans by water and swamp, only to be thwarted by an improvised militia of different racial castes and classes under the command of Major General Andrew Jackson. The Battle of New Orleans (January 8, 1815) put a decisive end to the incursion, the war, and Anglo-American hostilities. For New Orleans, the victory prevented a massive disruption to the functioning of the city (and possibly street fighting and widespread structural damage, as the British had done at Washington, DC). For our purposes, the disaster narrowly averted by the Battle of New Orleans is a case study of how diverse groups with contentious relations and conflicting interests may nonetheless unite and collaborate successfully against a common adversary.

The 1816 Carrollton Crevasse Flood

Crevasses (breaches) in the Mississippi River levee accounted for the city's worst non-epidemiological disasters in the 19th century, despite that they also imparted ecological services unrecognized at the time. "The waters rush" through a crevasse, wrote one visitor in the early 1800s, "with indescribable impetuosity, with a noise like the roaring of a cataract, boiling and foaming, and bearing every thing before them. Like the breaking out of a fire in a town, it excites universal consternation."

A complete chronology of river floods in New Orleans defies easy compilation because no single agency kept consistent detailed records until the late 1800s. According to one 1882 report, "partial inundations by the river" afflicted New Orleans in 1719, 1735, 1785, 1791, 1799, 1816, 1849, and 1862, while "partial inundations by Lake Pontchartrain or by this lake aided by the river" occurred in 1831, 1837, 1846, possibly in 1853, 1854–1855, 1856, 1861, 1868, 1869, 1871, and 1881. Data on lake floods prior to 1830 were either lost or never recorded, but such floods were "much more numerous" than overbank river flooding as levees improved. Gould's *Fifty Years on the Mississippi* adds 1780 to the list of colonial-era crevasse floods; Kendall's *History of New Orleans* (1922) adds 1813 to the record of crevasse floods and 1844 as a lake flood; and a recent Army Corps source adds 1850, 1858, 1865, 1867, and 1874 to the list of flood years. In 1890, high river water topped the levee in the French Quarter and, courtesy of an upriver crevasse, raised the level of the lake which thence flooded the lakeside marshes up to the Metairie Ridge. Another study found that the river reached flood stage at New Orleans (but did not necessarily inundate the city) once every 4.07 years on average, from 1871 to the 1930s. We focus here on the three most prominent crevasse floods, in 1816, 1849, and 1871.

On May 6, 1816, a weak spot in the levee on Barthelemy McCarty's plantation released water across present-day Carrollton and inundated the backswamp of the present-day Hollygrove, Fontainbleu, Broadmoor, and Mid-City neighborhoods, all mostly vacant at the time. The deluge rose up the backslope of the natural level to the rear flanks of the city. "One could travel in a skiff from the corner of Chartres and Canal streets to Dauphin," read one account, "down Dauphin to Bienville, down Bienville to Burgundy, thus to St. Louis Street, from St. Louis to Rampart, and so throughout the rear suburbs." Even with this destructive hazard came a valued river-borne resource: "the receding water," noted one historian, "filled the low terrain with alluvial deposits enriching the soil as well as elevating the swamp sections." That summer proved to be unusually healthy for the population—only 651 deaths occurred in New Orleans in 1816, compared to 1,252 in 1815 and 1,772 in 1817—probably due to the massive spring cleaning of the insalubrious port city.

The 1849 Sauvé Crevasse Flood

Thirty-three years after the Carrollton Crevasse, in spring 1849, rising river water began to undermine the levee fronting Pierre Sauvé's sugarcane plantation in what is now River Ridge in Jefferson Parish. Sauvé was not alone in this predicament; other planters eyed their softening levees worriedly. Those lining the Fortier parcel in present-day Waggaman on the West Bank were the first to fail, on April 17, but the water inundated mostly croplands and flowed harmlessly out Bayou Verret into Lake Cataouatche.

On May 3, Sauvé's levee finally breached. The torrent eroded the crevasse to 50 meters (164 feet) wide and 2 meters (over 6 feet) deep and destroyed everything in its path as it accumulated in the swampy lowlands of today's Elmwood and Jefferson. Because the Metairie Ridge (today's Metairie Road) restrained floodwaters from flowing northward toward Lake Pontchartrain, they instead spread eastward through what is now Mid-City, most of which was within Jefferson Parish and undeveloped at the time.

On May 8 waters reached a level high enough to subsume the New Basin Canal and its guide levees (now the I-10 corridor near Xavier University). Unlike those of the Fortier Crevasse, Sauvé's waters crept into urbanized areas, past Broad, Claiborne, and Dryades streets and into New Orleans city limits. The track bed of the present-day St. Charles Streetcar Line helped block the water from uptown, while downtown, floodwaters reached as far as Bourbon Street. But they went no farther east than present-day Lafitte Street, because, unlike those of the New Basin Canal, the guide levees of the Old Basin (Carondelet) Canal successfully blocked them (Figure 2). Although intermixtures of race and class generally predominated throughout the antebellum city, the rear-most blocks tended to be home to more socially vulnerable populations, including poor and marginalized groups such as recently manumitted slaves, and those areas suffered deeper inundation.

Volunteers plugged Sauvé's Crevasse on June 20, but not before 220 city blocks, 2,000 structures, and 12,000 residents were flooded. Within a few days, water exited out the two canals and Bayou St. John, percolated into the soil body, or evaporated. Displaced citizens returned home to clean up, and the city approved a special tax to fund repairs on damaged infrastructure. The deluge also left behind a "deposit of alluvion [with] vegetable and animal matter," worrying officials that an epidemic would follow.

Bad as it was, the 1849 deluge mostly soaked cane fields and woods. Although planters suffered crop losses, only about one-tenth of the flood footprint actually intersected with populated areas, and roughly the same percentage of New Orleanians found water in their homes, rarely deeper than half a meter (about twenty inches). The very deepest inundations measured two meters (six feet), and only in two small spots. These figures were all much worse during Katrina.

And whereas roughly fifteen hundred people died in 2005, few if any deaths were directly attributable to Sauvé's Crevasse. Contrary to officials' concerns, the flood may have actually saved lives. Only months earlier, cholera plagued the populace, but floodwaters and heavy rains had washed away filthy stagnant pools, and as had happened in 1816 after the Carrollton Crevasse, death rates actually declined. The environment also benefited, as the flood replenished the soil body with new fresh water and sediment, two resources needed by a delta to sustain itself against subsidence and the encroaching sea. In sum, while the crevasse in Sauvé's levee represented a genuine hazard to property and productivity, the population's residential exposure to its deluge was limited.

But, to Louisianians at the time, a levee had failed and floodwaters caused deprivation and loss. Understandably, they wanted improvements, as did other Americans settling along the Mississippi River. Much like Katrina, Sauvé's Crevasse became a rallying cry for better levees, and its high-water line would serve as a local benchmark for subsequent protection. A state law a few years later mandated that the levees along the New Basin Canal "shall be raised to the level of the high water from Sauvé Crevasse of 1849, so as to protect the city from inundation from any future crevasse."

Regionally, Sauvé's Crevasse and adjacent breaches added momentum to a congressional act passed a few months earlier in 1849, itself having been motivated by valley-wide floods in 1844. The Act to Aid the State of Louisiana in Draining the Swamp Lands ceded federally owned swamps to the state to encourage their reclamation and economic exploitation and generate revenue for levee enhancements. On the heels of the 1849 disasters, the so-called "Swampbuster Act" was expanded in 1850 to twelve additional states in the Mississippi Valley, plus two more elsewhere in 1860. Over the next century, this law would lead to the reclamation of sixty-five million acres of wetlands, producing wealth but also luring people into flood plains and setting up for inevitable flood losses. In Louisiana, the act helped pave the way for extractive and developmental activity in wetlands and marshes, which created jobs and revenue but also environmental losses through canal excavation and the impounding and drainage of swamps. As a result of these and other actions, the source of flood threat for New Orleanians would gradually shift from the Mississippi River to the Gulf of Mexico.

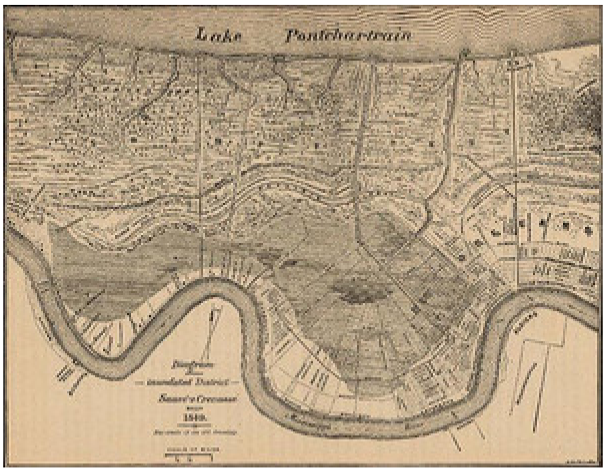

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Figure 2: Sauve Crevasse Flood of 1849 and its impact on New Orleans, at lower right.

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Yellow Fever

While fire and flood damaged the city structurally, disease killed by far the most people and disrupted economic and social life to the greatest degree. Cholera, malaria, and dengue claimed the lives of thousands, but it was the arbovirus called yellow fever that took the most: over 100,000 Louisianians and nearly 40,000 New Orleanians between 1796 and 1905. Worst outbreaks occurred during the late 1840s to late 1850s, during which time at least 22,500 perished; in 1853 alone, roughly one out of every ten residents —and a greater percentage of those who actually spent the summer in the city—perished.

Those with the most fiscal wherewithal and lowest social vulnerability responded to yellow fever by reducing their exposure to it, by fleeing to the safer climes of piney woods across Lake Pontchartrain, the Mississippi Gulf Coast, or the North. Those who could not, usually for reasons of class and racial caste including the subjugation of slavery, bore the brunt. The dreaded late-summer plague scared off vessels calling at the port and drove away visiting merchants, all of which stifled economic activity, which only intensified the trauma. The poor suffered more than the rich, for reasons of inequitable residential-settlement geographies, inferior domestic environs, and the lack of fiscal resources to travel. Immigrants and transients were thought to be the most prone to the maladies (so much so that yellow fever was called "the strangers" disease), for their lack of acclimation, while those of African ancestry and Creoles (locally born) were perceived to be more resistant, although this may well have been apocryphal. Late summer marked the most dreaded season: "I am now at the head-quarters of Death!" bemoaned one visitor in 1831, "and were it the month of August or September[,] I should scarcely expect to be alive this day [next] week."

This is not to say the other ten months were particularly safe: there were Asiatic cholera, smallpox, and other diseases which struck with little regard to season. The 1832 cholera epidemic alone claimed 4,340 lives and scared away another 11,000.

Authorities, informed by the best science of the day that the culprit was "miasmas"—that is, vaporous emissions rising from swamplands—futilely tried burning tar and firing cannon into the humidity. Other medical researchers hypothesized that standing water played a role. In a fascinating 1854 report, medical researcher Edward H. Barton plotted mortality rates from 1787 to 1853 against soil-disturbance events ("Canal Carondelet dug," "Trenches dug around the City & Swamp exposed," "Drained the rear of 2nd District," "Immense excavations [for] Customhouse," etc.) and detected certain correlations which would, in time, point to the role of stagnant water as habitat for the yellow fever vector. Similar research in Baltimore noted that yellow fever "was localized in low, wet areas" and "did not occur in high, dry areas." Doctors at the Medical College of Louisiana, forerunner to Tulane University, toiled toward solving this riddle, and in the process laid the groundwork for the medical research industry in the city today—an example of turning a public health disaster into an economic asset.

To both the relief and chagrin of New Orleanians, yellow fever deaths all but stopped during the Civil War, due in large part to the occupying Union Army's citywide cleaning and sanitation efforts. Once the city returned to local civilian control, public health crises recurred. Cholera stuck twice in 1866, and a yellow fever outbreak the following year claimed over three thousand lives. After four thousand died in 1878, civic society got into the act: realizing municipal hygiene was key, the private voluntary Citizens' Auxiliary Sanitary Association (1879) funded barges to load garbage and excrement, which were traditionally dumped into the river at various nuisance wharves, and haul them below city limits to be deposited in the middle of the current. The association also had river pumps and pipes installed to flush out city streets.

Discovery of yellow fever's true cause, infected *Aedes aegypti* mosquitoes, by U.S. Army doctors in 1900 ranks among the great medical breakthroughs of the era. But New

Orleans would need to respond to the conditions that exposed humans to this hazard before it could finally solve the problem. It would suffer one final epidemic in 1905, the nation's last, which killed over four hundred people.

With the vector and habitat now known, efforts doubled to drain the backswamp and, more importantly, install a water treatment and distribution system. Municipal tap water service would eliminate the need for cisterns, which provided ideal micro-habitats for infected mosquitos within meters of human blood meals. The twin systems were designed and installed during the 1890s–1900s and immediately had an effect. Wrote one observer in 1909, "there is a salubrity that could not be when the mosquito swarmed everywhere, when the level of supersaturation in the soil was but two and half feet from the surface . . . The curtains of swamp forest are totally gone. Their sites are drained dry and covered with miles of gardened homes." A land rush from the old riverside city into fashionable new lakeside suburbs ensued; assessed property value citywide grew during 1900–1914 by 80 percent, to $250 million. Death rates that ranged around 7 percent in the late 1700s and 4.3 percent in the 1800s declined to 1.8 percent in the two decades following the installation of the drainage, sewerage, and water systems. Malaria and typhoid deaths decreased tenfold, and yellow fever disappeared forever from the city.

Bubonic Plague

But soon a new hazard arrived: bubonic plague, the dreaded lymphatic disease spread by infected fleas on rats. Previously considered an Old World disease, Black Death had been in recession during most of the era of European contact with the New World, and the long journey across the Atlantic further kept at bay the bacteria and its vectors. This began to change when invasive rat populations had established themselves throughout the Americas and larger ships crossed the oceans faster and more frequently. The first Western Hemisphere case appeared in Brazil in 1899, followed by San Francisco in 1900 and Puerto Rico and Cuba in 1912. All were trading partners with New Orleans.

Concerned, officials launched a preemptive rat-trapping campaign in July 1912. Within days, they caught one infected rat, but found no others for the next two years. Then, in June 1914, a forty-nine-year-old Swedish sailor died, and an autopsy confirmed the cause to be bubonic plague. Others fell victim at a pace of one every three days for the rest of the summer. August 1914 saw the peak of the outbreak, just as war was breaking out in Europe.

But what could have been an epidemiological disaster instead became a resounding public health success. Key to the control of the epidemic was that federal, state, and city authorities took the earliest signs of the plague with utmost seriousness, and working with broad public support, pounced on every suspicious situation with overwhelming force and seamless cross-agency collaboration. A three-pronged prevention strategy was enacted upon both the hazard as well as human exposure. It aimed to reduce the rat population through a massive trapping campaign, find and destroy nesting and breeding "foci," and, finally, transform the cityscape to separate rats and humans as much as possible. Cases abated by year's end, but the campaign carried into the next year, when the city passed ordinances calling for the "rat-proofing" of buildings. Codes were put in place to get human living spaces raised above the land surface—an architectural tradition long practiced anyway for flooding reasons—while mandating gap-filled floorboards to be layered with concrete and barriers installed around crawl spaces. By the late 1920s, New Orleans was declared free of bubonic plague.

Because of the rigor of the New Orleans campaign, the 1914 outbreak was limited to thirty human cases and ten deaths, sparing possibly thousands from disfiguring illness and death. New Orleans' campaign would serve as a model for similar outbreaks elsewhere. "New York May Be Next [in] War on Rodents, Following Example of New Orleans," read a 1915 *New York Times* headline, which went on to detail "Boston, Philadelphia, and other important seaports" emulating the Crescent City's approach. The success shows that locally devised solutions to adversity can lay the groundwork for future economic strength. It also demonstrates, as did the Battle of New Orleans in 1815, the power of collaboration in the face of shared adversity: federal, state, and local authorities worked together seamlessly, and citizens cooperated supportively.

War, Wind, Water, and the Bonne Carré Crevasse: 1860s–1880s

Political and social turmoil dominated the 1860s–1870s period; in fact, more violent deaths occurred in New Orleans proper during the racially tense ten-year aftermath of the Civil War than during the conflict itself. The casualties occurred primarily in two racially driven political clashes in 1866 and 1874, the latter being essentially a coup d'état which helped bring about the end of Reconstruction and the reintroduction of white supremacist government. As for the Civil War, New Orleans succumbed peacefully to Union forces in May 1862, but the city could well have been bombarded had there been a miscommunication or overreaction during the tense moments of the actual takeover—another disaster narrowly averted. The remainder of the war saw federally coordinated sanitation efforts within New Orleans and, as previously discussed, a decline of disease. The 1860s did, however, see a potentially disastrous crevasse along the uptown riverfront, plus nine tropical storms and hurricanes causing varying amounts of damage. The worst non-political, non-epidemiological disaster of the postbellum era came in 1871, and once again, it came from the Mississippi.

In June of that year, a crevasse opened at a weak spot in the natural levee at Bonnet Carré, fifty river kilometers (thirty-one miles) above New Orleans. River water flooded the plantations but otherwise disembogued harmlessly into the lake—except that unusual easterly winds prevented those excess waters to flow out to the Gulf of Mexico. Lake levels thus swelled and penetrated inland courtesy of the manmade New Basin Canal, a navigation waterway excavated in the 1830s to connect Lake Pontchartrain with the Second Municipality. The rising canal water put pressure on the guide levees and on June 3, a spot failed at Hagan Avenue and flooded as far up Rampart Street, making the Bonnet Carré Crevasse of 1871 the city’s worst flood since 1849. It was also an early example of how ungated manmade canals can expose urban populations to flood hazards by inviting external waters into the metropolis, which was the essential circumstance of the Hurricane Katrina flood of 2005.

Bonnet Carré served as an impetus to reform water management in the region. Locally, city engineers in New Orleans proposed in 1871 an integrated system of protection levees and drainage networks; statewide, in 1886, Louisiana created levee districts to begin coordinating levee management efforts. Nationally, a new era dawned when Congress created the Mississippi River Commission in 1879 and directed it to work with the Army Corps of Engineers in controlling the lower Mississippi, representing a major shift of responsibility away from state and local control in favor of federal authority. Throughout the turn-of-the-century era, with the Commission “offering advice, serving as a clearing house for technical data, and providing two thirds of the funding required for construction, levees in Louisiana reached a new level of sophistication.” In 1890, the state created the Orleans Levee District and the Board of Levee Commissioners, charging them with the “construction, repair, control and maintenance of all levees in the District, whether on river, lake, canal or elsewhere . . .” With the help of the Board of State Engineers and other organizations, the modern Mississippi River levee system began to take shape. By 1892, nearly 400,000 cubic meters of soil went into constructing eight kilometers (five miles) of new levees and strengthening forty kilometers (twenty-five mile) of existing levees, with an additional 750,000 cubic meters added over the next four years. In 1907, earth-moving machines were introduced to the task, reducing construction costs by half while speeding the work and improving the quality. By the late 1920s, the Orleans Levee Board and its men had moved an additional 10 million cubic meters of soil to the New Orleans riverfront levees, to the exacting standards of the Commission.

While the massive earthen wall arising along the riverfront gave citizens a sense of security, the thinking behind it grew increasingly problematic from a river hydrology perspective. It was called the “levees-only” policy, and it derived from federally funded river research in the 1850s which sought navigation improvements as well as the prevention of Sauvé Crevasse–type floods. The research involved two competing surveys toward understanding how the Mississippi River might be controlled. One was led by military engineer Andrew Atkinson Humphreys, who theorized that a river restrained strictly by levees would dredge its own bed and thus create additional storage space for excess water. Civic engineer Charles Ellet, leading the other effort, suggested a more comprehensive approach which included levees as well as reservoirs and outlets to allow excess water to be stored laterally.

Levees only, or levees plus outlets? Authorities and experts debated and leaned toward the former. An 1873 document supporting the federalization of levees spelled out the reasoning behind “levees only”:

> The channel of the river is made by the abrasive force of its waters.
>
> A greater force would produce a greater channel. . . .
>
> The greater the channel for a given quantity of water[,] the less the liability to overflow.
>
> Concentration of force increases abrasive powers, and diffusion of force reduces it.
>
> Levees confine and concentrate the waters, concentrate and increase the flow, therefore increase the abrasion, therefore increase and enlarge the capacity of the channel.

“Outlets,” on the other hand, “diffuse the waters, reduce the abrasive forces, and therefore reduce the capacity of the channel.” During high water, a channel insufficiently scoured via levee constraint would overtop and flood adjacent lands. Hence, levees must be erected quickly—and exclusively.

The Army Corps officially adopted the levees-only policy in the 1880s and proceeded to realign, heighten, and strengthen the earthen dykes, eschewing all forms of spillways and lateral water storage to the point of sealing off natural distributaries. Nearly fifty years later, this policy would prove to be a terrible mistake.

The 1890–1895 Urban Fires

The 1890s were a time of transformative technological improvements. Electrification would come to replace oil and gas illumination; gas calefaction trumped coal; concrete pilings and steel supplanted timber in high-rise construction; and pumped treated water would soon replace collected rainwater or river water in homes and businesses. Cultural and economic change was afoot, too: Americans—at least white families of the middle class and higher—had more disposable income, and with rail lines crisscrossing the nation, leisure tourism and lodging came to New Orleans. But modernization in some realms galloped ahead of others, and the results were sometimes disastrous.

Two intense downtown fires serve to illustrate. The first ignited on Mardi Gras night 1890 and severely damaged the entire first block of Bourbon Street. Affected businesses had mostly rebuilt and reopened by February 1892, when, amid “a ceaseless procession [of] merry, happy” people patronizing “[s]aloons, restaurants, and other places,” a second fire started at Schwartz’s and spread rapidly. The flames “crossed [Bourbon] street in a bound,” and eventually destroyed twenty buildings and enterprises at a cost of $2 million. The 1890–1892 Bourbon Street fires exemplify how the private sector often responds to such disasters, especially those in high-value spaces: by pouncing on them as opportunities. Entrepreneurs built a luxury hotel and other amenities in the space of the ashes, and in time, would help launch the lucrative Bourbon Street we know today.

Three years later, in Algiers on the West Bank, the city suffered a near-replica of its last neighborhood-scale conflagration, in 1794. In the wee hours of October 20, 1895, a fire started in an overcrowded tenement house on Bermuda and Morgan streets. Strong dry northeasterlies rolled across the river and, as in 1794, drove the flames through the neighborhood. Algiers at the time, though incorporated into New Orleans since 1870, retained the look and feel of a rural village; most of its buildings were wooden frame houses or galleried pitch-roofed cottages of the Creole style, and many if not most dated from antebellum times, including the Algiers Courthouse, formerly a plantation house complete with old slave cabins. Firefighting and water pressure in Algiers were also behind the times. “The principal causes of the rapid spread of the flames were not only the scarcity of water and a furious wind,” stated the *Picayune*, “but the poor work of the fire department. When they lost control of the fire they became demoralized.” By noon, “nine and a half squares of ground [were] in ashes, and about twenty acres of a forest of chimneys standing [from] about 200 houses burned.” Although no one perished and few were injured, twelve hundred people were left homeless.

The city’s response to the disaster included the provision of shelter in a number of nearby buildings. Racial segregation, which since the end of Reconstruction had become codified into Louisiana law, persisted despite the devastation. “The negro churches in the rear of Algiers will serve as homes for the negroes who were burnt out,” the *Picayune* reported, “while the white people have rented stables and other outhouses.” Only about half of Algiers’ homeowner population could afford insurance; others, including poor renters, had no choice but to absorb losses. It is not clear who paid for food and shelter, but limited government involvement in humanitarian matters in this era oftentimes left such obligations to religious institutions or civic society, which in this era funded most of the city’s orphanages, alms houses, elder homes, asylums, and emergency shelters. As for

Algiers, the blocks were rebuilt within a short time, and to this day, the burned district is notable for its exclusively post-1895 Victorian Italianate styles, all older structures (including the courthouse) having been destroyed.

The 20th Century

An Unseen Topographical Disaster

Despite the fiasco of the 1895 Algiers fire, the turn of the 20th century saw promethean Progressive Era municipal improvements, from sanitation to water and sewerage treatment to parklands and, most of all, drainage. Historically, New Orleanians disdained their soggy backswamp as dangerous and unsightly, not to mention inhibitive of the city's expansion. Prior attempts to drain it had failed in the 1850s and 1870s, but by the 1890s, the will and wherewithal were in place to finally "solve" New Orleans' environmental "problem." Following a research and design phase (1893–1895) and financing in 1899, the Sewerage and Water Board proceeded to build a world-class system. It used natural topography to collect runoff via an intricate system of gutters, pipes, and below-ground canals leading to massive lift pumps, which would propel the water through newly excavated and/or widened outfall canals and into Lake Pontchartrain or other adjacent water bodies.

By the early 1900s, the system commenced removing impounded swamp water and lowering the ground water. It became more efficient in 1913, when a young engineer named Albert Baldwin Wood designed a new type of screw pump with an enormous impeller which would draw water out of the suction basin and into the discharge basin rapidly and efficiently. Eleven "Wood pumps" were installed by 1915; many are still in use today, and others have been adopted in China, Egypt, India, and the Netherlands. While Wood is often credited with draining New Orleans, he actually made an existing system faster and more efficient.

Modern subdivisions would soon be built upon the "reclaimed" land, with the encouragement of authorities who saw taxable real estate, developers who eyed lucrative house-building opportunities, bankers eager to lend mortgages, and upwardly mobile white middle-class families, who would settle into segregated subdivisions with racist deed covenants preventing black residency. So secure were New Orleanians in their technological salvation that the tradition of building houses raised on piers would eventually be abandoned in favor of cheaper slab-at-grade foundations.

The intervention, however, came at a cost. Drainage in New Orleans had been designed as a “closed” system, in that it viewed every drop of water as something to be removed, as opposed to a Dutch-style “open” approach, which views water as a necessary component of the landscape and attempts to store as much as possible in retention ponds to recharge the groundwater. New Orleans’ system succeeded all too well in removing the water component from the soil body—so much so that it opened up air cavities, which in turn allowed organic matter to decompose, shrink, and create more cavities. Finely textured alluvium settled into the air spaces, compacting the soil and lowering its elevation. New Orleans began to sink below sea level and become bowl-shaped in its topography. Pumps originally located behind populated areas—but which now found themselves surrounded by them—expelled runoff into the lake through outfall canals, which increasingly rose *above* the adjacent subsiding neighborhoods. Unbeknownst to new residents, their exposure to hazard grew with every centimeter their neighborhoods sunk, as did their dependence on pumps and barriers to prevent rainwater or sea water from pouring in. By time New Orleans’ municipal drainage system reached its hundredth anniversary, it and its counterparts in the suburbs had lowered half the metropolis below the level of the sea, by one, two, three, up to five meters.

The Great Storm of 1915

Six years after a relatively rare tornado damaged uptown, a major hurricane struck New Orleans. Arriving fifty years before Betsy and ninety years before Katrina, the unnamed, uncategorized tempest became known as The Great Storm of 1915, and in retrospect, it formed an inflection point in the city’s long history of disaster and response, as well as its urban risk formulation along the variables of hazard, exposure, and vulnerability.

Caribbean sailors first detected a tropical depression on September 22, a month after a hurricane killed over four hundred people in Galveston. By the time it turned toward New Orleans, wind speeds topped 135 miles per hour. An ominous “cirrus veil” clouded city skies on September 28, and after making landfall over Grand Isle, the system veered to position the city in the dreaded northeastern quadrant. By dawn on the 29th, winds in the city gusted at 40 miles per hour and steadily increased. Lake Pontchatrain’s waters swelled by two meters (six feet) while coastal and gulf waters rose five to seven meters (sixteen to twenty-three feet).

The surge overtopped the meager levees lining the lakeshore as well as adjoining outfall canals, the New Basin and Old Basin navigation canals, and Bayou St. John. “The overflow from these sources, [plus] about 7¼ inches of rainfall, was a most discouraging feature of this day’s development,” wrote an engineer afterwards. Salt water filled the bottomlands from present-day Broadmoor to Lakeview, which were still largely uninhabited at the time. “Over that portion of the city lying between the Old Basin Canal and Broadway and from Claiborne Avenue out to Lake Pontchartrain,” wrote famed forecaster Isaac Cline, “the water depth driven in by the storm ranged from 1 to 8 feet in depth.”

A bigger threat came from a crevasse in the Florida Avenue rear protection levee, which flooded the Seventh, Eighth, and Ninth wards. Meanwhile, the Mississippi River rose two meters (6 feet) above normal stage in uptown, and higher in St. Bernard and Plaquemines parishes, where it spilled over the levees and swept across the low country.

Gusts topped 100 miles per hour, paused, and around 6:35 p.m. reversed directions, as the eye passed just west of the city and pummeled Tangipahoa and St. Tammany parishes. New Orleanians peered out their windows and surveyed the damage. “CITY CUT OFF FROM REST OF WORLD,” read that evening’s *Item*. Nevertheless, the worst was over.

The next morning, sun shined over the Crescent City. Over twenty-five thousand structures experienced serious wind damage, including prominent landmarks. The deluge receded naturally everywhere except levee-encircled areas, where trapped water took four days to pump out. Damages exceeded $13 million region-wide, with roughly half occurring in New Orleans. At least 275 Louisianians perished. Cline, the nation’s top meteorologist, described the storm as “the most intense hurricane of which we have record in history of the Mexican Gulf coast and probably in the United States.”

Still, the marvel of the Great Storm of 1915 was not the extent of its damage, but its limit, given the system’s power. “*‘STORM PROOF!’ The Record Shows New Orleans*,” crowed the *Item*’s editorial page the day after. Indeed, the system arrived stronger and better positioned, compared to Hurricane Katrina in 2005, to devastate New Orleans utterly. Five reasons help explain why it did not.

First, an additional four thousand square kilometers (about fifteen hundred square miles) of healthy swamp and marsh padded southern Louisiana compared to today, and they helped absorb the surge before it reached the city.

Second, no major modern navigation canals allowed gulf waters to penetrate the city’s heart. The Industrial Canal was barely in planning stages; the Gulf Intracoastal Waterway did not yet exist; and the Mississippi River-Gulf Outlet Canal was not yet envisioned.

Third, the aforementioned municipal drainage system, brand new at the time, was conveniently in place to pump out standing water from within the bowl.

Fourth, that system, for all its effectiveness, had not yet had enough time to remove the water component from the soil body of the lakeside marshes—ergo, these areas had not yet subsided nearly as deeply below sea level as they would later. A less-deep bowl means shallower floodwaters.

Finally, urbanization of the lakeside marshes had barely begun by 1915; most New Orleanians remained on the higher ground closer to the Mississippi River.

Rather than inhibiting the development of these areas, the Great Storm of 1915 paradoxically encouraged it, by inspiring what became the Lakefront Improvement Project (1926) and other lakeside flood-control measures. This massive effort created new "reclaimed" high land in an effort to reduce the exposure to surges of residents settling near the lake. But it only encouraged more settlement, and thus more exposure. The paradoxical sequence demonstrated that, in coastal Louisiana as elsewhere, flood-control structures intended to protect people often end up luring them into harm's way. Those very areas secured by the Lakefront Project flooded severely during Hurricane Katrina, at a cost of hundreds of lives. "Floods are 'acts of God,'" observed geographer Gilbert F. White in 1942, "but flood losses are largely acts of man."

The Great Mississippi River Flood of 1927

In 1922, high water ripped a crevasse in the Mississippi River levee at Poydras in lower St. Bernard Parish, site of a former natural distributary which had been sealed off in accordance with the government's levees-only policy. In retrospect, its reopening might have been viewed as evidence against the wisdom of that forty-year-old Army Corps directive.

The thinking behind the levees-only policy was that a rigidly straightjacketed river would scour out its bottom and make room for excess water. Advocates were right in theorizing levees would prevent inundations most of the time. But they were wrong in presuming they could do so all of the time. Levee constraint did not "increase the abrasion" of the bottom of the river, as the previously cited 1873 report posited. Instead, it raised the bottom; excess sediment previously deposited laterally was now ending up in the bedload if it didn't get flushed out to the Gulf. Raising the bottom of the river, of course, raised the top of the river, which required higher levees, triggering further rise, motiving even higher levees. The vicious cycle would continue until extremely high flow would finally, inexorably, trigger a catastrophe.

In April 1927, intense rainfall in the interior led to epic flooding throughout the Mississippi Valley. Levees breached in numerous spots, and water filled over seventy thousand square kilometers (twenty-seven thousand square miles) of the ancient

Mississippi Embayment, driving a million people from their homes. The flood captured the attention of the nation, not to mention investors, who eyed New Orleans worriedly. Local commercial interests nervously assured them, quite correctly, that their levees were strong and sturdy. But when a lightning bolt from a routine downpour knocked out a pumping station and led to some water accumulation in city streets, press photographers in town to cover the river situation naturally snapped photos of the completely unrelated minor local street flooding. Those images made it onto the wires, and raised even more consternation on the part of outside investors. Powerful financial interests in New Orleans felt pressure to take decisive risk-reduction action. Their idea, probably motivated by a mix of inconsiderate avarice as well as genuine concern, was to dynamite a levee downriver to relieve pressure on New Orleans' levees by diverting water out of the stressed channel and into the coastal wetlands.

The Army Corps of Engineers stridently opposed the proposal, knowing all too well that other levees would fail upriver and yield the same effect. But state and local interests won the day. Sticks of dynamite were laid in the levee at Carnarvon, a short distance from the 1922 Poydras Crevasse, and following multiple attempts of intense blasting, the dyke finally gave way and a torrent flowed through. The floodwaters inundated poor rural Isleño, Creole, Sicilian, African American, Croatian and other trapping and fishing families, and they would never be fully compensated for their losses. The incident remains a bitter memory in rural-versus-urban, inter-parish relations to this day, and represents the historical memory from which were borne the rumors and conspiracy theories of intentional levee-blasting heard after hurricanes Betsy and Katrina.

The Great Mississippi River Flood of 1927 destroyed the illusion of "control" behind the levees-only policy, and replaced that ill-advised strategy with a more sustainable policy of accommodating the will of the river. It also motivated passage of the Mississippi River and Tributaries Act and the Flood Control Act of 1928, which cemented the federal government's commitment to a massively augmented flood control system—even as it exempted the government from liability should it fail. While the previous policy exclusively prioritized for levees, the new approach called for multiple tactics: levees would be still be raised, broadened, strengthened, and extended, but they would be joined by upriver dams, weirs, and locks designed to withhold and store excess water while also providing irrigation, hydroelectricity, and domestic water needs. Significantly, the post-1927 interventions would also include nonstructural devices to divert high water into adjacent areas. Spillways—which are essentially controlled crevasses—were installed at Bonnet Carré and Morganza to serve as "safety valves" during flood stage, officially defined as when the river flows at 17 feet (5.18 meters) above sea level at the Carrollton Gauge, or 1,250,000 cubic feet (35,400 cubic meters) per second in volume. The Madrid Floodway in Missouri, as well as the Old River Control Structure (1954–1962), could also be marshalled to store or reroute excess water. The Mississippi River still potentially threatens New Orleans, as evidenced by the fact that the Bonnet Carré Spillway has been opened in 1937, 1945, 1950, 1973 (which damaged Old River), 1975, 1979, 1983, 1997, 2008, and most recently in 2011. But this is one hazard that, at least for New Orleans proper, had been brought under control. The post-1927 system worked flawlessly in 2011, which saw the highest river water since 1973. Had this occurred in the 19th century, it likely would have resulted in a Sauvé Crevasse–style deluge.

The 1947 Hurricane

The human catastrophe of World War II actually benefited New Orleans economically, which saw its boat-manufacturing sector boom and its population soar from 494,537 in 1940 to 559,000 by 1945. The postwar metropolis, under the leadership of progressive reformer Mayor deLesseps "Chep" Morrison, looked confidently toward expansion and modernization, as urbanization stretched to the lake and new trade opportunities opened up in Latin America and the Caribbean. Then, in 1947, the metropolis experienced its first disastrous setback in a generation.

The Hurricane of 1947 wrought considerable damage to the Fort Lauderdale area before making landfall at New Orleans on September 19. Mayor Morrison assured citizens that improvements made since the Great Storm of 1915, including the burial of power lines to key pumps and the construction of the upraised Lakefront (1926–1934), would get the city through the crisis. Most residents sheltered in place, at home or in neighborhood schools and other sturdy public buildings.

But there were two other post-1915 port projects that were anything but improvements for storm surge risk reduction: the Industrial Canal, dug between the river and lake in 1918–1923, and the Gulf Intracoastal Waterway, which was excavated in stages, completed in 1943, and later widened to allow domestic barge traffic to move west and east. Both manmade waterways allowed surge water to enter unimpeded from the north via the lake and the east via the Gulf.

Winds of over 100 miles per hour buffeted the city at dawn, and the eye passed over downtown at mid-morning. Surge rushed through the Bayou Bienvenue swamps and marshes, which were healthy enough to absorb much of the water and energy but not enough to prevent a levee breach along Florida Avenue in the rear of the Lower Ninth Ward, where vulnerable populations of mostly African Americans lived. Low-lying sections of Gentilly saw splash-over water and street flooding. Other parts of the lightly populated eastern ramparts of Orleans and St. Bernard parishes inundated, as well as Jefferson Parish on the west side of the 17th Street Outfall Canal (the same canal that would fail catastrophically during Katrina, though on the opposite side).

The 1947 storm and flood killed fifty-one people and caused $100 million in damages. But local government and business interests seemed intent on restoring the city's image vis-à-vis tourism and investment, and at one point took out full-page ads in local newspapers blaring "Hurricane? New Orleans Breezed Through It!" The Hurricane of 1947 plus a subsequent September 1948 storm did, however, motivate additional levee work along the lake shore and adjacent marshes, marking the beginnings of the lateral hurricane-protection levees which would become the first line of defense in future decades. Those new barriers would be increasingly needed after the ill-advised Mississippi River-Gulf Outlet Canal was excavated in 1958–1968 and the eastern swamps and marshes subsequently died from salt water intrusion—just in time for New Orleans' next major disaster.

Hurricane Betsy

On August 26, 1965, a tropical depression formed in the southern Caribbean and grew to a tropical storm—the second of the season, named "Betsy"—as it moved northwestwardly, only to stall north of Puerto Rico. Now a hurricane, the system slowly resumed, stalled again, jumped straight west and struck Miami–Key West, then darted northwestwardly at twenty knots. Betsy's stunning bolt across the Gulf of Mexico robbed coastal residents of precious hours needed for evacuation; nevertheless, 90 percent of the quarter-million people in the southeastern Louisiana coastal zone found shelter inland or on higher ground.

In New Orleans, "evacuation" meant not the major metropolitan exodus practiced today but micro-scale, intra-urban movement to sturdier public structures. With over 600,000 city residents (many without vehicles) and no modern interstate highways, a mass flight was neither possible nor recommended. Most New Orleanians felt safe in the city and "rode out" the storm at home or in neighborhood schools; coastal residents evacuated *to* levee-protected New Orleans.

Radar systems picked up Betsy's eye at 11:03 a.m. September 9; eleven hours later, it made landfall directly over Grand Isle. The northwestward path meant the fiercest winds buffeted the Barataria Basin and the river towns of Venice, Buras, and Port Sulphur. Low barometric pressure and strong winds lifted and pushed a dome of gulf water inland, to two meters (six feet) above mean sea level in Pascagoula, Mississippi, and over three meters (ten feet) in the newly excavated Mississippi River-Gulf Outlet (MR-GO) Canal connecting with New Orleans. The swollen Gulf backed the Mississippi River up upon itself, forcing water over the levees along the river's lowermost eight-five kilometers (fifty-three miles). In New Orleans proper, the river rose from a normal late-summer stage of one meter (three feet) above sea level to over four meters (thirteen feet). Betsy's surge was the highest recorded to date, due in part to the sheer forward speed of the storm.

Hurricane Betsy pummeled New Orleans proper around midnight of Thursday-Friday, September 9–10, accompanied by thirteen centimeters (five inches) of rain falling over thirty hours. Winds in metropolitan New Orleans sustained at 75–85 miles per hour and gusted to 110–125 miles per hour After Betsy's weakening eye proceeded past Baton Rouge at dawn Friday, it drifted inland and eventually petered out in Ohio.

Were an aerial image snapped as dawn Friday, September 10, most of southeastern Louisiana would have blended seamlessly with the Gulf of Mexico except for the natural levees of the Mississippi River and Bayou Lafourche plus the levee-protected western half of metro New Orleans. Flooding within New Orleans occurred mostly along three man-made navigation canals scoured into the eastern marshes during the previous five decades: the Industrial Canal, the Gulf Intracoastal Waterway, and the adjoining MR-GO. The surge penetrated five of the city's dozen hydrological sub-basins via levee-overtopping and breaching, particularly along the west side of the Industrial Canal from Florida Boulevard and Claiborne Avenue. Water filled sections of the Seventh, Eighth, and Ninth wards, racially mixed working-class neighborhoods which suffered 6,350 homes and nearly 400 businesses under water. The water failed to surpass the Gentilly Ridge but nevertheless backed up the drainage canals that traverse it, resulting in over a meter of flooding in an all-white portion of Gentilly and the adjoining all-black subdivision of Pontchartrain Park.

Hardest hit of all was the Lower Ninth Ward. A series of Industrial Canal levee breaches plus overtopping deluged the poor, mostly black section, by 1–1.5 meters (3–5 feet) along St. Claude Avenue and 3 meters (10 feet) along the back levee. Only the streets closest to the Mississippi River—present-day Holy Cross, a majority-white working-class area at the time—evaded the deluge.

Hurricane Betsy claimed the lives of 81 Louisianians, injured 17,600, and caused $372 million in damage, about one-third in New Orleans proper. Its greatest cost, however, came in the form of unlearned lessons. As part of the Betsy-inspired Lake Pontchartrain and Vicinity Hurricane Protection Project, federal, state, and local efforts proceeded to strengthen levees around the basins flooded by Betsy, expand residential developments into them, augment the very canals that ushered Betsy' surge inland, and design new levees to standards that Betsy demonstrated to be obsolete. The project was never fully funded and only partially executed, but enough flood-protection devices were installed to greenlight urbanization into ever lower-lying and far-flung areas. Once again, New Orleanians unknowingly increased their exposure to future hazards as residential developments opened in increasingly peripheral and low-lying former marshes.

The Social Disaster of White Flight, 1960s–1990s

Underlying the vulnerability and exposure variables in New Orleans' urban risk formulation are spatial patterns of race and class. Racial settlement geographies in antebellum times formed a surprising spatial heterogeneity, a byproduct of urban slavery and masters' desire to lodge the enslaved proximately for reasons of convenience and control. After emancipation, this pattern gradually diminished, as large numbers of emancipated peoples from surrounding plantation regions emigrated to the city and generally settled along its backswamp edge, exposing them to the nuisances and maladies of the city's margins even as other forms of suppression kept them vulnerable in terms of fiscal, social, and human capital. Racial spatial disassociation in residential settlement patterns exacerbated further after the draining of the former backswamp in Gentilly and Lakeview, where, as previously mentioned, subdivisions exclusively for white residency were built. Schools, workplaces, and spaces throughout the public domain remained strictly de jure segregated, including the housing projects, the two of which for whites only were located in the higher "front of town," and the four for blacks only being in the lower-elevation "back of town."

Tremendous social transformations forged new racial relationships in the latter half of the century. Chief among these were *Brown v. Board of Education of Topeka* (347 U.S. 48, 1954), the Civil Rights Act of 1964, and the ensuing desegregation of public facilities, integration of public schools (starting 1960–1961), and increased opportunities in education, employment, and housing for African Americans. Jim Crow disappeared with less violence and resistance here than in other southern cities; black and white New Orleanians subsequently found themselves working, shopping, and dining together in increasing numbers. Yet living together did not necessarily follow; in fact, residential integration diminished. Suburban-style subdivisions in Jefferson, St. Bernard, and St. Tammany parishes, even as far as coastal Mississippi, drew white New Orleanians by the tens of thousands between the censuses of 1960 and 2000. Middle-class uptown and lakeside whites generally gravitated westward into Metairie and Kenner in Jefferson Parish, while working-class downtown or riverfront whites usually resettled eastward in St. Bernard Parish or on the West Bank. Middle-class African Americans, for their part, mostly moved lakeward to the neighborhoods east of City Park and thence into the subdivisions of eastern New Orleans.

"White flight" in the 1960s and 1970s, and the broader pan-racial middle-class exodus of the 1980s–2000s, had the effect of shifting fiscal and political power outwardly into suburban parishes, while leaving divestment, a lower tax base, deprived populations, and deteriorating infrastructure in the inner core. For our purposes, it may be considered a "social disaster" on a number of grounds, one of which is the fact that, more so than any prior physical or epidemiological disaster, the demographic exodus occasioned the city's first and only major decline in population—from a peak of 627,525 in 1960 to around 455,000 just prior to Katrina. Incredibly, despite all the traumas documented in this article, from the flood of 1719 to the epidemic of 1853 to Civil War and floods, fires, and hurricanes, the population of the city steadily, sometimes stridently, increased in every decade from the early 1700s to 1960. It took a voluntary exodus provoked by racial animus, at least initially, to spark the very first (and, to date, only) decline in the city's population. Worse, the suburban exodus also caused the city to plummet in rankings among America's largest cities. Having peaked in 1840 as the third largest city in the nation and the largest in the South, New Orleans stabilized in the twelfth to sixteenth range in the early to mid-20th century. The exodus would cost it five increments of ranking per decade, such that, by the 21st century, New Orleans ranked as the thirty-first largest city in the nation—and among its poorest.

Avulsion Averted: The 1973 Mississippi River Flood and the Old River Control Structure

The highest water on the Mississippi River since 1927 occurred in 1973, and while the powerful current had no direct effect on New Orleans, it did damage a major piece of engineering infrastructure on which New Orleans depends utterly: the Old River Control Structure, built in the late 1950s to prevent a river-channel jump (avulsion) that has "wanted" to happen since the 1830s. Had the river switched channels, it would have left New Orleans without a shipping port and a fresh water supply.

About eighty river kilometers (fifty miles) south of Natchez, the Mississippi changes its geomorphology and hydrology, and the "funnel" formed by the Red and Mississippi river valleys join to form a narrow "spout." Here, the Red once flowed into the Mississippi at the tip of a meander loop, called Turnbull's Bend, while a distributary, the Atchafalaya, flowed out and through south-central Louisiana to the Gulf of Mexico.

Two events in the 1830s altered the course of history here—and very nearly altered the course of the Mississippi. In 1831, Captain Henry Shreve severed Turnbull's Bend, in the interest of shortening travel time, by digging "Shreve's Cutoff" across the narrow neck. Almost immediately, the Mississippi lunged into the cutoff and made it its main channel. Meanwhile, the severed meander, dubbed Old River, silted up in one portion while another section continued to usher the Red into the Mississippi. Little water escaped out the Atchafalaya because a massive natural logjam, the Red River Raft, clogged the channel.

Eight years later, the state of Louisiana started clearing the logjam in the interest of navigation and development. But what the removal of the barrier also did was provide the Mississippi with a shorter path and steeper gradient to the sea. Subsequently, increasing quantities of both the Red and the Mississippi began to flow down the 370 relatively steep kilometers (230 miles) of the Atchafalaya's channel, rather than the 800 relatively flat kilometers (497 miles) of the lowermost Mississippi. By the mid-20th century, the Atchafalaya had tripled its share of Mississippi water and seized most of the Red's. Scientists by that time predicted the Mississippi would eventually jump channels around 1975, abandoning New Orleans and converting Louisiana's invaluable river corridor to an elongated brackish bay.

To prevent this catastrophe, the Old River Control Structure was built in 1954–1962 to regulate the flow of the Mississippi into the Atchafalaya at a ratio of 70-to-30, meaning that for every ten units of water approaching the structure, seven would continue in the main channel of the Mississippi toward New Orleans while three would flow down the Atchafalaya toward Morgan City. This ratio, which was selected because it was the status quo at the time of the intervention, today requires congressional approval to be adjusted for any reason. The Old River Control Structure represents one of history's most Herculean engineering projects, and when the 1973 flood damaged it, greater New Orleans came close to an unprecedented disaster—not one that would have destroyed property or killed people, but would have made the metropolis economically and hydrologically unsustainable, sans a port and a water source.

Invasive Species

Disasters need not be dramatic or acute to have disastrous impacts; witness the city's deadly bouts with plagues traceable to minute vectors arriving at Louisiana's door. Other invasive species have incurred expensive chronic problems and may well be categorized as ecological disasters.

Four particular invasive species have caused disproportionate damage to regional ecology and society, and topping the list is the previously described *Aedes aegypti* yellow fever mosquito native to Africa. There is also the water hyacinth, a lush aquatic plant with a beautiful purple flower introduced as an ornamental at the 1885 World's Industrial and Cotton Centennial Exposition at Audubon Park. Finding ideal habitat, hyacinth by the 1890s established itself throughout the region, clogging waterways, out-competing native aquatics, starving water of light and oxygen, and creating mosquito habitat. In the late 1890s, Congress appropriated funds "to investigate the obstruction of the navigable waters of Florida [and] Louisiana . . . by the plant known as the water hyacinth"—a costly and constant battle which continues to this day.

Even more damaging to coastal wetlands are nutria, large furbearing rodents from Argentina imported to Louisiana in the 1930s. Intentionally released animals as well as escapees subsequently spread throughout the coastal marshes, oftentimes aided by state officials, who viewed nutria as a boon to fur trappers. They were—until the 1980s, when fur fell out of fashion in favor of leather coats. Pelt prices plummeted five-fold and nutria spread exponentially, damaging marshes by devouring grasses and exposing thin soils to wind and water erosion. A state bounty program has since motivated some trappers to pursue nutria again, but with phenomenal reproductive rates and a wide geographical range, these invasive rodents will remain a permanent part—and cause—of the shrinking Louisiana landscape.

While nutria destroy wetlands near New Orleans, insects devour its buildings. During World War II, vessels arriving from East Asia unknowingly brought inside their wooden pallets a tiny winged pest, Formosan termites, which found an agreeable climate and plenty of wooden housing stock in the port cities of Houston, Mobile, and New Orleans. For years, the household pesticide Chlordane drove Formosans out of treated structures and into urban trees, weakening them structurally and oftentimes causing their collapse. When Chlordane was banned in 1988, Formosan termites proceeded to infest houses. Subsequent control attempts by the U.S. Department of Agriculture and local entities have, at best, only stabilized the problem, which has since spread to the entire southern tier of the United States and costs New Orleanians well over $300 million annually.

The 21st Century

Hurricanes Georges, Isidore, Lili, Ivan, and Cindy, 1998–2005

In August 1995, satellite images captured four massive Atlantic tropical systems edging westward along the North Equatorial Current toward the Americas. The moment marked the beginning of an uptick in tropical activity which continues to this day, in a time of climate change and possible increases in storm frequency and power.

By the time Hurricane Georges struck on September 28, 1998, scientists had become convinced, and word had reached policymakers and citizens, that a century’s worth of soil subsidence, coastal erosion, and sea-level rise would bring storm surges dangerously close to levee-rimmed, bowl-shaped New Orleans. Officials responded by discouraging coastal denizens from taking refuge in the metropolis, and dissuading New Orleanians from sheltering locally as they had done traditionally. Now the strategy was evacuation. Luckily, a last-minute meteorological twitch pushed Georges eastward and mostly spared

New Orleans, but not before tens of thousands of families fled in the city's first large-scale evacuation—only to find themselves mired in horrendous traffic jams.

Then came hurricanes Isidore and Lili in 2002 and Ivan in 2004, the last of which triggered another full-scale metropolitan evacuation. By then authorities were deploying the new "contraflow" system of routing outbound traffic on inbound lanes. The careful planning and inter-agency coordination required for contraflow would take time to perfect, and the 2004 evacuation proved to be even more tortuous than 1998. Ivan, too, spared the city, and in retrospect it may have taught a detrimental lesson, in that it made officials seem too eager to call for evacuations. "Hunkering down" at home, or depending on shelters-of-last-resort, seemed like acceptable alternatives, especially for those without cars or cash.

The 2005 hurricane season opened when a sloppy early-July tropical storm named Cindy came ashore. Under-predicted and underreported, the storm caused a startling amount of wind damage, darkened the electrical grid, left local broadcast meteorologists red-faced, and later matriculated in the record books as a Category-1 hurricane. Cindy reminded that hurricanes are complex, multivariate phenomena defined by uncertainty, and the way we categorize them oftentimes oversimplifies them, underreports hidden dangers, and misleads the public.

Hurricane Katrina

On August 23, 2005, tropical air fueled by unusually warm ocean water spiraled above the Bahamas. The system grew sufficiently for the National Hurricane Center to classify it as Tropical Depression 12, and by the next morning, as Tropical Storm Katrina. On August 25–26, Category-1 Hurricane Katrina struck North Miami, killing nine people, and re-strengthened in the Gulf of Mexico.

With Katrina now a Category-3 storm and computer models now all concurring on a Louisiana landfall, the regional population mobilized on Saturday August 27. Emergencies were declared and officials activated the contraflow plan. Many departed Saturday; more left Sunday, when the system strengthened to Category 4 and 5 levels within five hours.

The evacuation window had all but closed by Sunday night, as feeder bands whisked over the city. Roughly 100,000 New Orleanians—2 of every 9—remained in the city, and of those, approximately 15,000 lined up outside the Superdome, expecting at least a safe if uncomfortable night in this shelter of last resort. Overwhelmingly they represented the most socially vulnerable portions of the city's population.

As dawn broke, sea water began to overtop the Gulf Intracoastal Waterway and MR-GO Canal guide levees in the Bayou Bienvenue marshes of St. Bernard Parish and the Lower Ninth Ward. Shortly thereafter, a breach opened in the western floodwall of the Industrial Canal, sending water into the Upper Ninth Ward. A similar failure developed on the 17th Street Outfall Canal, flooding Lakeview.

Hurricane Katrina made landfall at 6:30 a.m. between Grand Isle and the mouth of the Mississippi and moved straight north on a track east of New Orleans proper. Although wind speeds had abated to Category-2 levels and lower, storm surge retained Category-5 momentum, swelling three to ten meters (ten to thirty-three feet) above normal sea level, while Lake Pontchartrain's waters rose by three meters (ten feet) and canal waters by four to five meters (thirteen to sixteen feet). This put pressure on soft peat beneath the floodwalls, and concrete-encased steel sheet pilings (flood walls) did not penetrate sufficiently deep into the earth to curtail the seepage. Around 7:00 a.m., two lengthy sections on the Lower Ninth Ward's Industrial Canal floodwall caved in from below, and high-velocity salt water five meters (sixteen feet) above normal levels gushed into a neighborhood that lay 1.3 meters (4.3 feet) below sea level.

By 9:00 a.m., when most of low-lying New Orleans East lay under water, breaches multiplied on the drainage outfalls to the west: on both sides of the London Avenue Canal, at a preexisting low spot on the Orleans Avenue Canal, and at the crack in the 17th Street Canal, which widened into a major collapse. Now Lakeview experienced the same high-velocity torrent suffered earlier by the Lower Ninth Ward. St. Bernard Parish to the east fared even worse, while Jefferson Parish to the west saw rainwater and spillover accumulation because parish personal had been evacuated and the pumps remained offline. Neighborhoods in the Hoey's Basin section of Metairie, hydrologically connected to Orleans' drainage system, flooded deeply as well.

Many journalists, overly focused on Katrina' east-of-the-city track and diminishing intensity, mistakenly reported Monday afternoon that New Orleans had "dodged the bullet." Not until Tuesday did it become clear that levees had failed in numerous spots and low-lying areas were filling deeply with sea water. Evacuees learned a jolting new truth: their flood-protection and drainage system had *not* neutralized hydrology and topography; New Orleans' ancient geographies of hazard, supposedly subjugated by technology generations ago, had revealed their obscured relevance. Centuries of manipulating the deltaic plain had allowed the "enemy" to get too close to the "fort." Decades of subsidence had turned the city inside the fort into a vulnerable "bowl," while years of underfunding and under-engineering had turned the supposedly fortified bowl into a drowned city.

Scattered across the country, residents came to learn that their federal flood-protection system was a system in name only—piecemeal, disjointed, shoddily engineered, poorly maintained, sloppily inspected, underfunded, and oversold. They would come to understand that the Army Corps of Engineers, the Federal Emergency Management Administration (FEMA), and other agencies at all levels bore responsibility for various elements of the fiasco, but that the Corps, as per the Flood Control Act of 1928, is not liable for flooding caused by the failure of federal flood-control devices (though it may be for navigation canals; litigation is pending). Local experts, meanwhile, learned they had been worrying too much about the tolerable problem of levee overtopping, and too little about the unthinkable catastrophe of levee collapse.

Volumes have been written about the recovery and evolution of post-Katrina New Orleans. For our purposes, three major episodes of the postdiluvian years are highlighted:

The Great Footprint Debate: A fierce civic debate ignited in late 2005, while most citizens were still evacuated, over whether the urban footprint should be "shrunk." Under such a scenario, the smaller postdiluvian population would be more safely positioned on higher ground closer to the historic urban core, while outlying subdivisions on lower elevations could be returned to nature as surge buffer. In essence, footprint shrinkage aimed to decrease exposure to hazard and thus reduce urban risk. Despite its pragmatic appeal and geophysical rationality, "shrinking the urban footprint" failed utterly by early 2006, and for understandable reasons: its actual execution would have been socially divisive, fiscally exorbitant, legally complex, and politically volatile. Any politician who supported neighborhood closure would have been deposed by constituents; besides, no vast federal fund existed for the fair and swift compensation of expropriated landholders. FEMA's updated flood insurance maps, meanwhile, sent a message of actuarial encouragement for status quo resettlement, and the Road Home Program's Option 1—to rebuild in place, by far the most popular of the three choices (more on this later)—provided grant money to do exactly that. What prevailed instead was a stance that essentially said, *let people return and rebuild as they can and as they wish, and we'll act on the patterns as they fall in place*. All neighborhoods would reopen, though not all neighbors would return to them. Those with the highest social vulnerability, including the poor, elderly, minorities, and families with children, tended to come back at the lowest rates.

The Road Home Program: Starting in 2006, the federally funded, state-administered Road Home Program began to distribute up to $150,000 per eligible homeowner, minus insurance settlements and FEMA grants, to those whose homes suffered more than 50 percent damage. Participants could choose Option 1, to repair or rebuild in place; else they could sell their lot to the state and purchase another home in Louisiana (Option 2); or sell and choose not to remain a homeowner in Louisiana (Option 3). The lengthy and slow bureaucracy of the Road Home Program soon enraged the citizenry, delaying their rebuilding decisions while dooming Governor Kathleen Blanco's reelection efforts. Worse, the method to determine Option 1 compensation, which was based on the pre-Katrina property values rather than the cost of materials and labor, had the effect of discriminating against those who happened to live in lower-income areas, usually minorities. This flaw was later acknowledged and adjusted by a court decision, but not before creating more turmoil and paperwork for beleaguered flood victims. By Katrina's second anniversary, less than one-third of the 140,000 eligible applicants closed on their payments. Later that year, a bill added $3 billion to the program, and most of remaining applicants would close over the next few years. By 2015, according to the program's website, "130,000 residents across the Louisiana coastal region[,] over 99% of eligible applicants[,] have received more than $8.9 billion to rebuild and protect their homes and rental properties from future storm damage." Those who sold their properties to the state, which constituted the minority in most neighborhoods with the exception of the Lower Ninth Ward, had their titles transferred to the state's Louisiana Land Trust (LLT). Over time, the LLT transferred titles to the city's New Orleans Redevelopment Authority (NORA), which proceeded to sell, auction, or divide parcels between neighbors through the "Lot Next Door" program. NORA is currently devising alternative sustainable uses for unsold lots, such as water storage, urban agriculture, and green space.

The Risk Reduction System: Working in a streamlined design-build fashion, the Army Corps of Engineers and its contractors constructed during 2007–2011 a $14.5 billion flood protection system—officially renamed the Greater New Orleans Hurricane and Storm Damage *Risk Reduction* System (emphasis added)—to guard the metropolis from surges produced by storms with a 1 percent chance of occurring in any given year. Unique in the nation, the system comprises closable gates and bypass pumps on the outfall canals, a rock-barrier closing of the MR-GO, an immense, Dutch-style 2.8-kilometer-long barrier across the "funnel" formed by the GIWW and MR-GO, sector and sluice gates on various navigation and drainage canals, the world's largest pumping station plus closable gates on the West Bank's West Closure system, plus heightened and strengthened levees (to the tune of 76 million cubic meters of clay) and floodwalls with deeper-driven sheet piling. The result is roughly the equivalent of the system that New Orleanians had been promised after Hurricane Betsy, but had never been delivered.

Roughly $71 billion federal dollars, plus countless volunteer efforts on the part of other Americans and the sweat, toil, and tears of New Orleanians, helped stabilize the city by the 2010s, even as its education, housing, justice, and infrastructural systems remained anything but stabilized.

Hurricane Gustav

Coming within days of the third anniversary of Katrina, Hurricane Gustav tested New Orleanians' recent Katrina-based edifications. The storm was powerful, though certainly not as strong as Katrina, and this time the levees and floodwalls (in the midst of the aforementioned upgrades at the time) prevented a repeat of 2005. The evacuation passed muster as well, in part because authorities had been inculcating the public about preparing for such a scenario. A new system of public buses ensured those without cars did not get left behind, and it too worked reasonably well. There were no more refuges of last resort; nearly everyone evacuated—and this time, everyone knew to empty their refrigerators, an oversight in 2005 that led to the destruction and costly disposal of hundreds of thousands of fetid appliances. Officials succeeded in securing the city before the strike and guarding against looting during and after Gustav's assault on the emptied city. They also allowed people to take pets on evacuation buses, a new policy which prevented a repeat of heart-wrenching dramas in 2005 often involving children. And they let evacuees return as soon as possible so they could bring their stilled city back to life. While evacuations can save thousands of lives if a catastrophe like Katrina happens, they are otherwise expensive and disruptive (witness Ivan and Georges). Residents wondered: can a modern metropolis survive three months annually under the constant threat of massive life interruption? Or would this major competitive disadvantage drive away families and investors and eventually winnow the population down to that of a Venetian-like boutique city?

The BP Oil Spill

Like the Katrina deluge, the BP Oil Spill of April-July 2010 had a century-long backstory. Modernization in the early 1900s created ever-increasing nationwide demand for fossil fuels, which Louisiana's geography had stored in great quantities both onshore and offshore. The state's first commercially viable oil well was drilled in Jennings in 1901, and within a decade, oil pipelines, oil refineries, oil jobs, oil law, and oil money became integral to the local and national economy. A poor state eager to attract whatever investment it could, Louisiana willingly collaborated with industry, accepting revenue and jobs in exchange for massive intrusions upon its environment. The political and commercial class reveled in the ensuing production of wealth, and ordinary citizens did not protest the flow of tax revenues coming out of the industry's earnings rather than their own pockets.

Onshore deposits ran dry within a generation, sending the search for oil into nearshore areas starting in 1947, then farther offshore in the 1950s–1960s, then into the kilometers-deep waters of the Gulf of Mexico in the 1980s. The Macondo well, drilled in 1998, targeted the Mississippi Canyon eighty kilometers (fifty miles) southeast of the mouth of the Mississippi River, where a vast deposit of petroleum lay below the sea surface. The leak that followed the April 20, 2010, explosion occurred because of a sequence of engineering mishaps for which BP had developed a notorious reputation—and for which eleven men paid with their lives.

From the BP Deepwater Horizon disaster, residents of the region learned first-hand lessons on topics such as surface slicks, tar balls, containment booms, dispersants, oil-eating microbes, and the relationships among ecology, culture, and economics. While New Orleans proper largely evaded the deleterious effects beyond a slight downturn in tourism and related spending, fishermen in Plaquemines and St. Bernard parishes and travel destinations throughout the region suffered the most, as did oil and gas workers in places like Houma on account of the moratorium on offshore drilling imposed by President Obama. Researchers today continue to assess the state of the Gulf's recovery, which remains an open question, and new engineering and safety rules are now in effect for offshore drilling.

Hurricane Isaac

Precisely seven years after Katrina and nearly four years since Gustav, Hurricane Isaac imparted New Orleanians with their latest brush with disaster. As Cindy taught in July 2005, citizens relearned from Isaac that storm categorizations can be deceptive and overly simplistic, especially after the 2009 elimination of storm surge estimations from the Saffir-Simpson 1-through-5 hurricane categorization scale. Many residents made the mistake of shrugging off Isaac on account of its Category-1 status, only to startle at its strong surge driven on a 45-degree-angle track, with metro New Orleans positioned in the dreaded northeastern quadrant.

The completed Risk Reduction System had convinced authorities not to declare a mandatory evacuation—and properly so. Whereas Katrina and Gustav warranted mandatory evacuations, Isaac did not, and authorities should be credited for resisting the litigiously tempting instinct to "err on the side of caution." So residents huddled at home as Isaac slowed and meandered erratically for two days, giving it more time for surge, wind, and rain to do their damage. Fortunately, the rain was fairly well distributed, but the winds left nearly the entire region without power for three to six days.

The new Risk Reduction System worked exceedingly well for those inside its walls. But it also affected where the storm surge went outside the wall, if only by a few centimeters, according to post-storm Army Corps modeling. This much is clear: surge flooding during

Isaac occurred in places that hadn’t flooded before, such as Laplace in St. John Parish, relatively far from open Gulf waters. After Isaac, calls arose from residents of these area to extend the Risk Reduction System around them as well—and in some spots, it will be.

Isaac reiterated a lesson delivered repeatedly since the 1990s: that while structurally engineering our way out of this problem may extend the life of this metropolis for another few generations, long-term sustainability will come only when we figure out how to rebuild sinking, eroding coastal wetlands at a pace faster than the level of the sea is rising. Given the low supply of sediment in the Mississippi and the costly, legally complex, and economically disruptive nature of diverting sediment and freshwater onto the coastal marshes, our time window in which we can reverse this situation is closing. The Army Corps’ success in fast-tracking massive structural engineering projects during the post-Katrina years now must be replicated for nonstructural coastal restoration.

Conclusion

An inventory of New Orleans’ three-century history of disaster and response brings to light larger trends in the nature of regional hazards and the exposures and vulnerabilities of the population. For one, the city’s premier source of hazard has shifted away from the Mississippi River and to the Gulf of Mexico. Residents of the metropolis no longer worry about river floods, as their ancestors did; modern levees and the post-1927 system of spillways and floodways have largely ended threats of the river to the city proper. But those same levees have depleted the deltaic plain of the fresh water and alluvium, and combined with the erosive capacity of thousands of kilometers of oil, gas, and navigation canals, have led to the disappearance of roughly 5,000 square kilometers (1,900 square miles) of coast buffer. Rising sea levels in the face of these eroding and subsiding coastal wetlands have since made the Gulf of Mexico the chief source of hazard to New Orleans.

Secondly, New Orleanians have augmented their exposure to this hazard by expanding their urban footprint both horizontally and vertically. Convinced in the early 20th century that the natural factors which previously constrained their residential geography had been neutralized, residents migrated enthusiastically out of older higher neighborhoods and into lower modern subdivisions. While all New Orleanians lived above sea level in historical times, only 48 percent remained above sea level by 1960; fully 321,000 New Orleanians had vertically migrated from higher to lower ground since the early 1900s. Subsequent years saw tens of thousands of New Orleanians migrate horizontally as well, primarily for social and economic reasons. By 2000, New Orleans’ population had dropped by 23 percent since its 1960 peak, representing a net loss of 143,000 mostly middle-class white families to adjacent parishes. Testifying to the level of unimportance ascribed to human exposure to hazard—and implicitly, the faith placed in drainage and flood control—most of those fleeing New Orleans proper unwittingly ended up living on lower (and lowering) ground. By 2000, only 38 percent of Orleans Parish residents (and coincidently 38 percent of all residents of the contiguous metropolis south of Lake Pontchartrain) lived above sea level. Many of these areas flooded during Katrina, and nearly all of them bear higher flood insurance rates today, despite that the recently completed Greater New Orleans Hurricane and Storm Damage Risk Reduction System now provides a stronger barricade between the source of hazard and exposed populations.

Finally, the level of vulnerability of the population remains among the highest in the nation. Research by geographer Susan Cutter ranks roughly half of the census tracts of the New Orleans metropolitan area as highest (top quarter) in the nation for overall vulnerability, based on thirty socioeconomic statistics collected by the U.S. Census and computed into a Social Vulnerability Index (SoVI).

There is good news: two of the most-feared hazards of historic New Orleans, viral disease and conflagration, have long since been brought under control, and New Orleanians worry about them no more or less than people elsewhere in the developed world. But the variables of urban risk related to the distinctive circumstances of this deltaic environment point to a questionable future for this fascinating but troubled metropolis, and make calls for coastal restoration as well as socioeconomic improvements all the more pressing.

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