Physical Geographies

Part I

Geographies of New Orleans
by Richard Campanella
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Geological New Orleans

New Orleans, one of the nation's elder cities, lies upon the youngest sizable earthen surface of North America. The Crescent City has stood for almost 6 percent of its physical terrain's life span, a percentage dwarfing that of other American cities.[1] New Orleans' land base is only ten times older than its oldest living biota (live oaks), twenty times its most aged buildings, and fifty times the age of its most senior citizens. So young is the region that geologists often collaborate with archeologists in investigating their respective disciplines: geology and human history practically share the same timeline, and recent human artifacts often lie *beneath* thick strata deposited by natural forces. "This alluvial country is truly curious," wrote Edouard de Montulé in 1817.

> When they dug a basin behind New-Orleans, they found everywhere several layers of tree trunks, and in one of them, fifteen feet below the present level, an iron axe, evidently of European make. It had probably come down with a tree trunk from the vicinity of Pitzburg, on the Ohio, a region inhabited by the French a long time before Louisiana.[2]

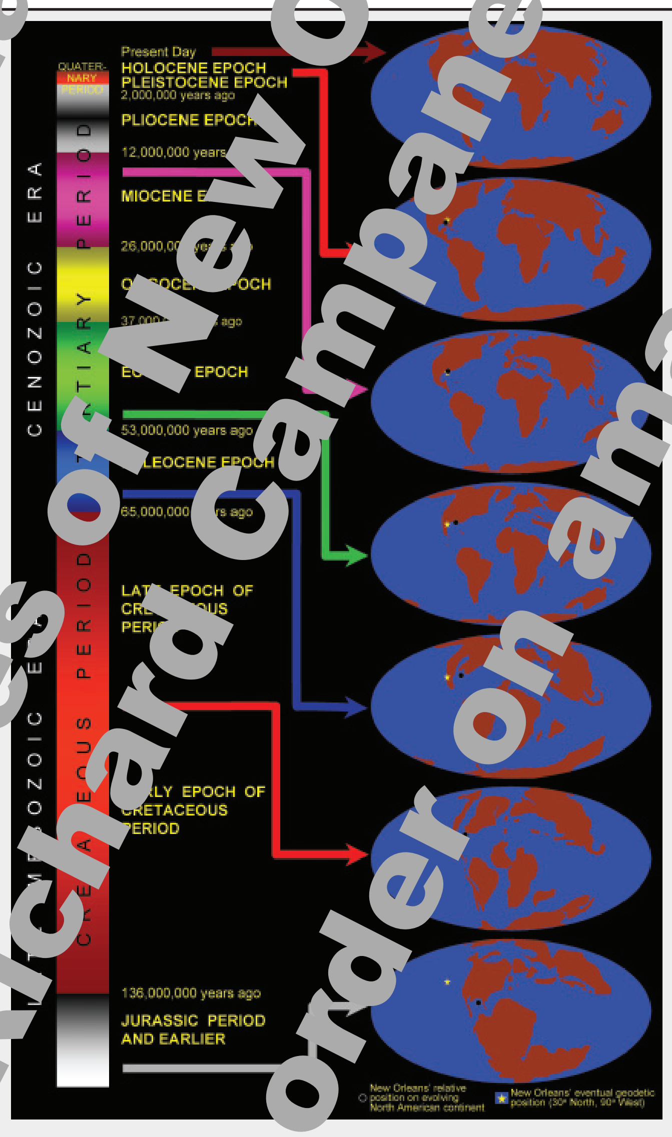
New Orleans' perch upon the deltaic plain of the Mississippi River makes the city a one-of-a-kind metropolis in its experience with geology.

Adrift Across the Planet

A sense of geographic destiny underscores New Orleans' location. What better place for a city than near the mouth of a vast continent's greatest river, where waterborne access to a fertile basin may be controlled from a single point? Even New Orleans' [illegible] compiled geodetic coordinates—30° North, 90° West—suggest a sense of order in the world, a need for this city to exist. But the geographical situation seized in the early 1700s to become the New Orleans we know today was a long time in the making, and even longer just to arrive at its present location, a sixth-of-a-planet above the Equator and a quarter-planet west of Greenwich.

A half billion years ago, continents practically unrecognizable today were distributed mostly across the southern hemisphere.[3] During the next 250 million years, underlying tectonic plates drifted together to form the supercontinent Pangaea. Named by the German scientist Alfred Wegener (1880-1930) who first proposed the radical hypothesis of continental drift, Pangaea spanned from present-day Europe to Antarctica, roughly straddling the Greenwich Meridian. Within the supercontinent were the nestled landmasses whose shapes we would come to recognize as today's continents. The general footprint of ancestral North America, called Laurentia, put the relative situation of future New Orleans in the middle of the Atlantic Ocean along the Equator. But this locale, in the Permian Period, was landlocked by the future continents of South America and Africa, fitted snugly around what would become the southeastern United States.

Over the next one hundred million years, during the Jurassic Period, the tectonic plates underlying North America and Eurasia drifted away from the nestled mass of South America, Africa, India, Australia, and Antarctica, thus creating a nascent Atlantic Ocean and the beginnings of a Gulf of Mexico. Future New Orleans was now roughly at 10° North, 60° West, near present-day Trinidad, and drifting northward and westward. New Orleans' river/gulf juxtaposition, however, was not even embryonic at this time: the southern edge of North America was well inland of its present-day coast-



A sense of destiny underscores New Orleans' geographical situation, astride North America's greatest river, gateway to a vast and fertile basin. Its formation was a long time in the making. Shown here, from the bottom up, are the theorized positions of the drifting continents from the Jurassic Period to the present, with future New Orleans' relative position shown as a black point, and its eventual absolute location (30° North, 90° West) as a yellow star. *Graphic by author based on C.R. Scotese and other sources.*

[1] Southeastern Louisiana, once thought to be 5,000 years old, is now estimated to be roughly [illegible] 20[illegible] years old. The land-building deltas of the Mississippi River that formed New Orleans proper commenced 4,000-5,000 years ago. Allusions to the age of the New Orleans land base in this discussion imply approximately 5,000 years.

[2] Edouard de Montulé, *Travels in America 1816-1817*, trans. Edward D. Seeber (Bloomington, IN, 1951), 91.

[3] Data for this section were interpreted from a wide range of source materials, among them Brian F. Windley, Philip Kearey, Seiya Uyeda, and Charles Schuchert. Maps were adapted from Christopher R. Scotese's "Paleomap Project: Global Plate Tectonic Model," www.scotese.com.

line, and neither the Mississippi Valley nor its river was yet formed. Then, as the continent drifted, it also rifted apart internally, forming an expansive trough through the middle of North America.

A very different planet emerged by the Cretaceous Period, about one hundred million years ago, as the components of former Pangaea separated into distinct continents and sea level rose to levels higher than the Earth has seen in the past three hundred million years. The rising waters split North America in half with a vast epi-continental seaway spanning from the present-day Rockies to the Appalachians, and from the Arctic Ocean to the Gulf of Mexico. It was during this period that central North America's crust warped downward along the path of the present-day lower Mississippi River. This important feature, forefather of the Mississippi Valley, is called the Mississippi Embayment, described by geologist Roger T. Saucier as "a northward synclinal projection of the Coastal Plain that lies between the southern Appalachians and the Ouachita Mountains"[4] of Arkansas. New Orleans' relative situation, if one were to project it upon this alien Cretaceous geography, was located roughly at 24° North, 77° West, a position east of present-day Miami, Florida, and still far offshore.

By the time of the disappearance of the dinosaurs—sixty-five million years ago, at the beginning of the Cenozoic Era—sea level had dropped precipitously. The continent's bifurcating seaway had retreated in the north, but still flooded most of the coastal and central-southern (that is, the Mississippi Embayment) portions of North America, making New Orleans' situation still a watery spot hundreds of miles offshore. This position, if mapped upon today's globe, would be located off the coast of Jacksonville, Florida, around 30° North, 80° West.

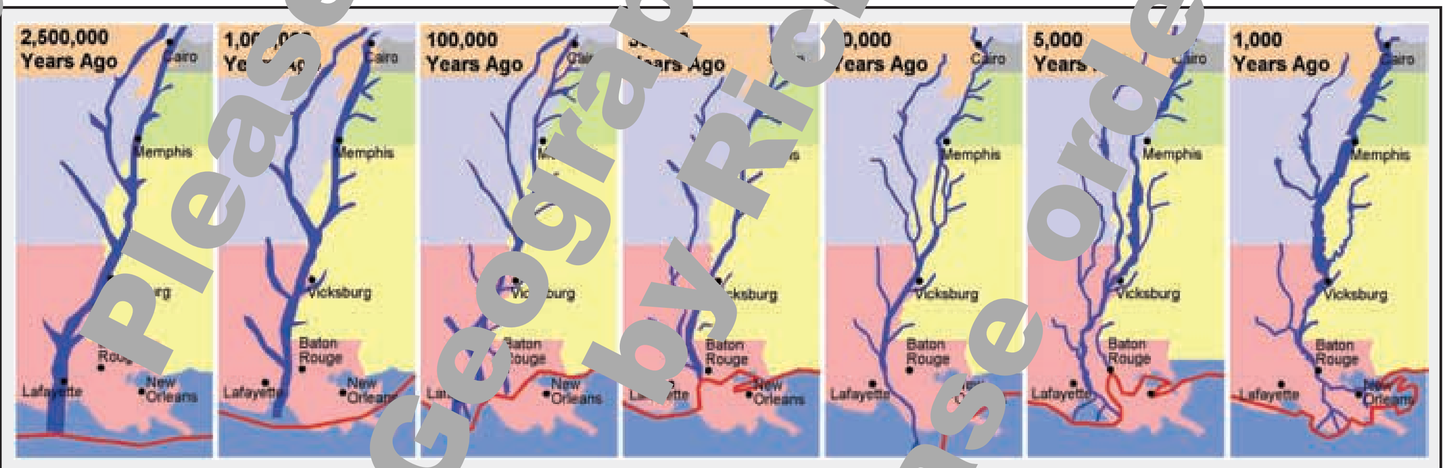
By the Eocene Epoch, the Mississippi Embayment—once 1,000 feet deep and intruding up the present-day Mississippi Valley to southern Illinois—had been drained of retreating seawater and mostly sedimented, rendering the shape of the continent we recognize today (sans Florida). The continent's southern coast was now (about fifty million years ago) sufficiently developed such that we can identify future New Orleans' situation relative to it, though it remained hundreds of miles from the city's modern-day geodetic position. Over the next tens of millions of years, the sea repeatedly transgressed and regressed into the Mississippi Embayment, depositing after each cycle. "The overall effect was a single major regressive sedimentary cycle continuing [up to two to three million years ago]; as a consequence, the edge of the continental shelf prograded southward about two hundred miles to its present location."[5] With the Gulf Coast now more or less "in place," the relative and absolute positions of the future city of New Orleans would finally coincide by the Middle Miocene Epoch, around fifteen million years ago. This did not mark the end of continental drift, only another stage of it. Nor did the formation of North America's modern coast with the Gulf of Mexico mean that a Mississippi Valley yet adjoined it, a Mississippi River yet discharged into it, or a river-dominated delta yet formed upon it.

Formation of the Mississippi Valley

It is now the Pleistocene Epoch, about two million years ago. The Gulf Coast at this time traced a smooth arc from the present-day Florida panhandle through Mobile, Baton Rouge, Lake Charles, Houston, Corpus Christi, and into coastal Mexico. Running five hundred miles northward into the North American interior was the now-drained, now-sedimented Mississippi Embayment, which still exhibited its downwarped configuration, a valley formed not by adjacent mountains but by an indentation in the Earth's crust. Runoff from the surrounding landscape collected in this valley, forming a primordial Mississippi River. Had these conditions persisted, a river of regional importance—perhaps the size of the Tennessee or the Red—might have developed, with a small delta near present-day Lafayette or Baton Rouge. It was the Missouri, not the Mississippi, that drained the eastern Rock-

[4] Robert T. Saucier, *Geomorphology and Quaternary Geologic History of the Lower Mississippi Valley*, 2 vols. (Vicksburg, MS, 1994), 1:51.

[5] Ibid.



Generalized meander belts of the lower Mississippi River, from 2,500,000 years ago to 1,000 years ago, with corresponding coastlines of Gulf of Mexico. *Graphic by author based on Saucier. Some channel depictions are for illustrative purposes.*

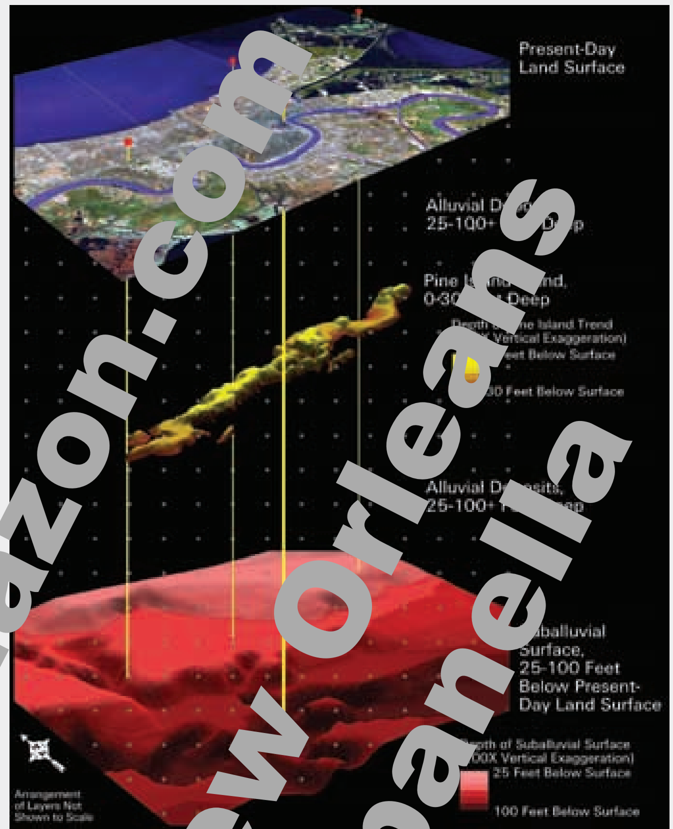
ies, plains, and upper Midwest at this time, also discharged into the Hudson Bay, not the Gulf of Mexico.[6]

The Pleistocene Epoch also saw the beginning of a relatively rare event in the history of the planet—in fact, the last one to date: an Ice Age. As temperatures dropped, ice sheets expanded and advanced southward across North America, taking up water at the expense of the sea, whose level thus declined. Then temperatures increased, the ice sheets receded, and sea level rose. This cycle repeated about five times over the past two million years, reaching the coldest point about eighteen thousand years ago (glacial maximum), when the ice sheets reached their southernmost extent. With each glacial advance, the dropping sea level rendered 30° North, 90° West a landscape instead of a seascape. Sea level may have reached as low as 450 feet below the current level, placing the coastline well south (near the Continental Shelf) of its current position. The future New Orleans site might have exhibited a climate like that of the present-day upper South or Midwest, with a gently sloping topography of small clay hills, perhaps like that of Arkansas or Mississippi. The Ice Age also dramatically transformed the waterway we now call the Mississippi River.

Formation of the Mississippi River

At glacial maximum, the edge of the northern ice sheet sprawled westward along what is now the Missouri River and eastward along the Ohio. The relationship between the border of the glacier and the channels of these rivers was causative: the ice sheet, called the Illinoian Advance at this stage, radically rearranged the rivers' drainage patterns by pushing them to its edge, forcing them to conflow at its southernmost point. That point was located at the northernmost point (present-day Cairo, Illinois) of the Mississippi Embayment. Glaciers thus redirected waters running off vast expanses of North America into what was previously a relatively small river winding broadly in a wide meander belt, transforming it into the greatest drainage system on the continent. The Mississippi River was borne, the Mississippi Basin was established, and the Mississippi delta was about to develop.

The expanding Mississippi was now delivering increasing quantities of both water and sediment to the Gulf of Mexico, and began to attain the magnitude and path we know today. The exact paths of the lower Mississippi's historical meander belts—that is, the flat, broad expanses, bordered by bluffs, within which the actual channel shifted—is not known for certain. Roger T. Saucier, foremost expert on the subject, wrote in 1994 that "it is difficult if not embarrassing for geologists to admit that during the past fifty years, we have taken at least two major steps backward rather than forward" in understanding "the chronology of Holocene Mississippi River meander belts."[7] Once the meandering river exited its alluvial valley and entered the Gulf of Mexico, it slowed its velocity and dropped its sediment load, forming a delta—"a



New Orleans' landscape once undulated with twenty-five to fifty-foot-high clay hills formed during the Pleistocene Epoch. Rising seas and seven millennia of sediment deposition covered this surface with twenty-five to one hundred feet of alluvium, forming the present-day land surface. Also buried by the river-borne sediment was a former barrier island created by the Pearl River and pushed westward by longshore currents of the Gulf of Mexico. This feature, known as the Pine Island Trend, helped form Lake Pontchartrain by trapping rising sea water behind it. The relict island now lies up to thirty feet below lakeside Orleans and Jefferson parishes. *Map and GIS processing by author based on research by Saucier/Army Corps of Engineers.*

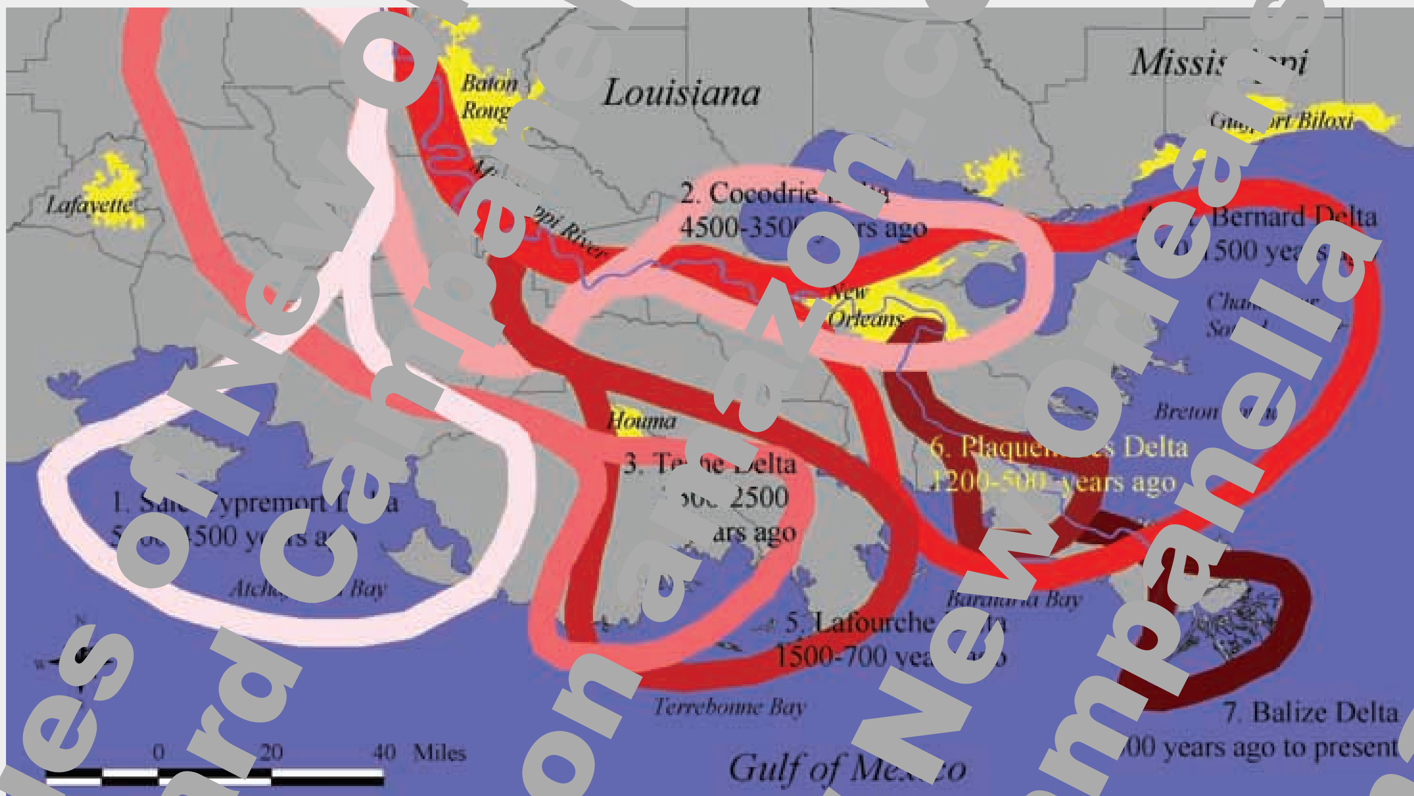
body of sediment laid down by dynamic sedimentary processes…where a river...enters a deeper and less turbulent body of water."[8] This delta would, in time, form a plain that is now southeastern Louisiana, and host the site for New Orleans—but only when the changing level of the sea would allow it to accumulate.

At the Sangamon Stage (125,000 years ago), the delta comprised a small discharge zone between present-day Lafayette and Baton Rouge, while a much smaller delta developed at the mouth of the Pearl River, on the present-day Louisiana/Mississippi state line. There, gulf currents carried the Pearl's sand deposits westward to what is now eastern New Orleans, where they formed a sandy beach known as the Pine Island Trend. By 70,000 year ago (Eowisconsion Stage), the Mississippi delta forked near Old River, one branch flowing into the modern-day Mississippi channel, the other in the Atchafalaya River channel. Over the next 60,000 years, the lower river jumped channels and generally meandered within the area known today as the Atchafalaya Swamp, while its

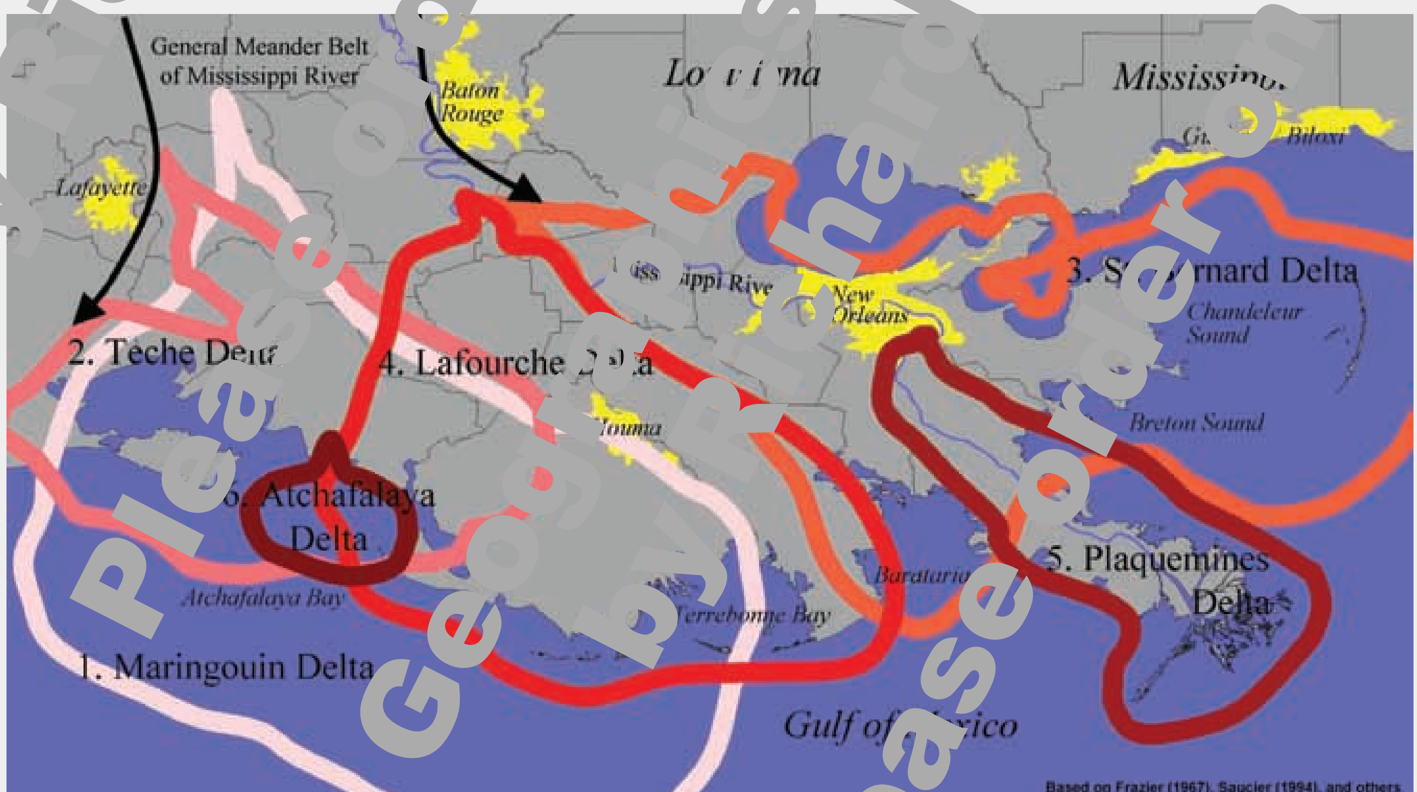
[6] Ron Redfern, *The Making of a Continent* (New York, 1983), 142.
[7] Saucier, *Geomorphology and Quaternary Geologic*, 1:253.
[8] Ibid., 136.

terminus advanced as far as fifty miles off the present-day coast and receded as far inland as present-day Port Allen.[9] In addition to depositing sediment at its mouth, the river coated its banks with alluvium dropped during seasonal overbank flooding. Yet, despite all this deposition, no substantial, lasting deltaic plain developed, and no southeastern Louisiana formed. Why? Sea level during these times fell, rose, fell, and rose again, interrupting the land-building process and scattering the sediments offshore rather than allowing them to

[9] Ibid., 2:Plate 28, Sheets 1-3.



Southeastern Louisiana formed over the past 7,200 years, as the lowermost two hundred to three hundred miles of the Mississippi River jumped channels and deposited sediment throughout 20,000 square miles along the Gulf Coast. Scientific research has shed light on the locations, dates, and shapes of these delta complexes. The top map shows the Russel/Fisk and Kolb/Van Lopik interpretation from the 1940s and 1950s; the bottom map shows Frazier's 1967 refinement using radiocarbon dating and other methods. (Shades of red indicate the delta complex's age.) The New Orleans area is mostly a product of the St. Bernard and Plaquemines deltas, starting roughly [illegible],000 years ago. *Maps by author based on Russel, Fisk, Kolb, Van Lopik, and Frazier.*



accumulate in a plain. In the latter stages of the Ice Age, "the rate of postglacial sea level rise was so rapid that it is unlikely that a deltaic plain analogous to that of today was able to form."[10] Starting around 12,000 to 10,000 years ago, the rate at which sea level rose started to diminish. Gulf currents still carried off sediment, but to a lesser degree and at a slower pace. Now a new environment awaited sediments bound for the sea via the Mississippi River.

Formation of the Mississippi Deltaic Plain and New Orleans Region

Starting about 7,200 years ago, river-borne sediments were decreasingly overwhelmed by the rising sea, and thus started to accumulate at the river's mouth. The Mississippi's repeated seizing and re-seizing of the steepest gradient toward the sea resulted in not one accumulation at one mouth, but a series of widely divergent ones. These deltaic complexes, containing numerous sub-deltas (lobes), roamed an area two hundred miles west-to-east and one hundred miles north-to-south over the course of seven millennia. Places as far west as coastal Vermilion Parish and as far east as the waters off Biloxi, Mississippi, were influenced by the outflow of vast quantities of fresh, muddy water. It is from these recent geological events that we mark geological time in southeastern Louisiana. Even though the underlying Pleistocene clays and sand bars such as the Pine Island Trend are much older, the topographic surface, arable soils, and coastline came about only as this recent alluvium began to amass.

To the French geographer Elisée Reclus (1855), the deltaic portion of the lower Mississippi River resembled "a gigantic arm projecting into the sea and spreading its fingers on the surface of the water."[11] American geographer John McPhee described the lowermost river as jumping "here and there within an arc about two hundred miles wide, like a pianist playing with one hand—frequently and radically changing course, surging over the left or the right bank to go off in utterly new directions."[12] Geologists have, since the 1930s, generally agreed upon where this "hand" landed over the millennia, though its exact extent, movements, eras, and "fingers" (lobes) have been debated and refined. In the 1940s, geologists R.J. Russell and H.N. Fisk identified six delta complexes and subdivided them into a number of sub-deltas. In 1958, C.R. Kolb and J.R. Van Lopik updated these findings with seven deltas of the Mississippi River, assigned some new names, and mapped them as distinctive lollipop-shaped lobes. The general consensus at this point was that the complexes and thus the age of southeastern Louisiana spanned roughly the last 5,000 years.

[10] Ibid., 1:277. See also graph of historic sea level variations on page 49.

[11] Elisée Reclus, "An Anarchist in the Old South: Elisée Reclus' Voyage to New Orleans, Part II," trans. Camille Martin and John Clark, *Mesechabe: The Journal of Surre(gion)alism* 12 (1993-1994), 19.

[12] John McPhee, *The Control of Nature* (New York, 1989), 5.

Deltas of the Mississippi River, According to Kolb and Van Lopik (1958)

Name of Delta Complexes	Years Ago	General Location
Salé-Cypremort Delta	5,000-4,500	Atchafalaya Bay, around Franklin
Cocodrie Delta	4,500-3,500	St. John, St. Charles, Jefferson, and Orleans parishes
Teche Delta	3,500-2,500	Terrebonne Parish, around Houma
St. Bernard Delta	2,600-1,500	Orleans and St. Bernard parishes
Lafourche Delta	1,500-700	Thibodaux and Bayou Lafourche region
Plaquemines Delta	1,200-500	Upper Plaquemines Parish, from English Turn to Empire
Balize Delta	500 to present	Lower Plaquemines Parish, below Venice

Based on Kolb and Van Lopik (1958), as interpreted by Fred B. Kniffen and Sam Bowers Hilliard, *Louisiana: Its Land and People* (Baton Rouge and London, 1988), 54. Overlapping periods indicate divergences of river, forming multiple deltas.

According to the 1958 study, New Orleans proper was first directly coated by Mississippi alluvium by the Cocodrie Delta, starting about 4,500 years ago, then by the St. Bernard Delta. Sediment also layered the future New Orleans area during the years of the Plaquemines and Balize deltas, not because the Mississippi discharged there but because, during high water, it overflowed its banks and deposited sediments upon it.

The influential research of Kolb and Van Lopik is still widely cited today. In 1967, the understanding of delta complexes was further modified by David E. Frazier, based on radiocarbon dating and other new technologies. Frazier identified five delta complexes of the Mississippi River, subdivided them into sixteen delta lobes, determined that many functioned contemporaneously, and estimated that the entire land-building event transpired over 7,200 years. Other researchers have since added to the body of knowledge on the origins of southeastern Louisiana, but according to Saucier, "Frazier's work remains the most definitive to date."[13]

Deltas of the Mississippi River, According to Frazier (1967) and Others

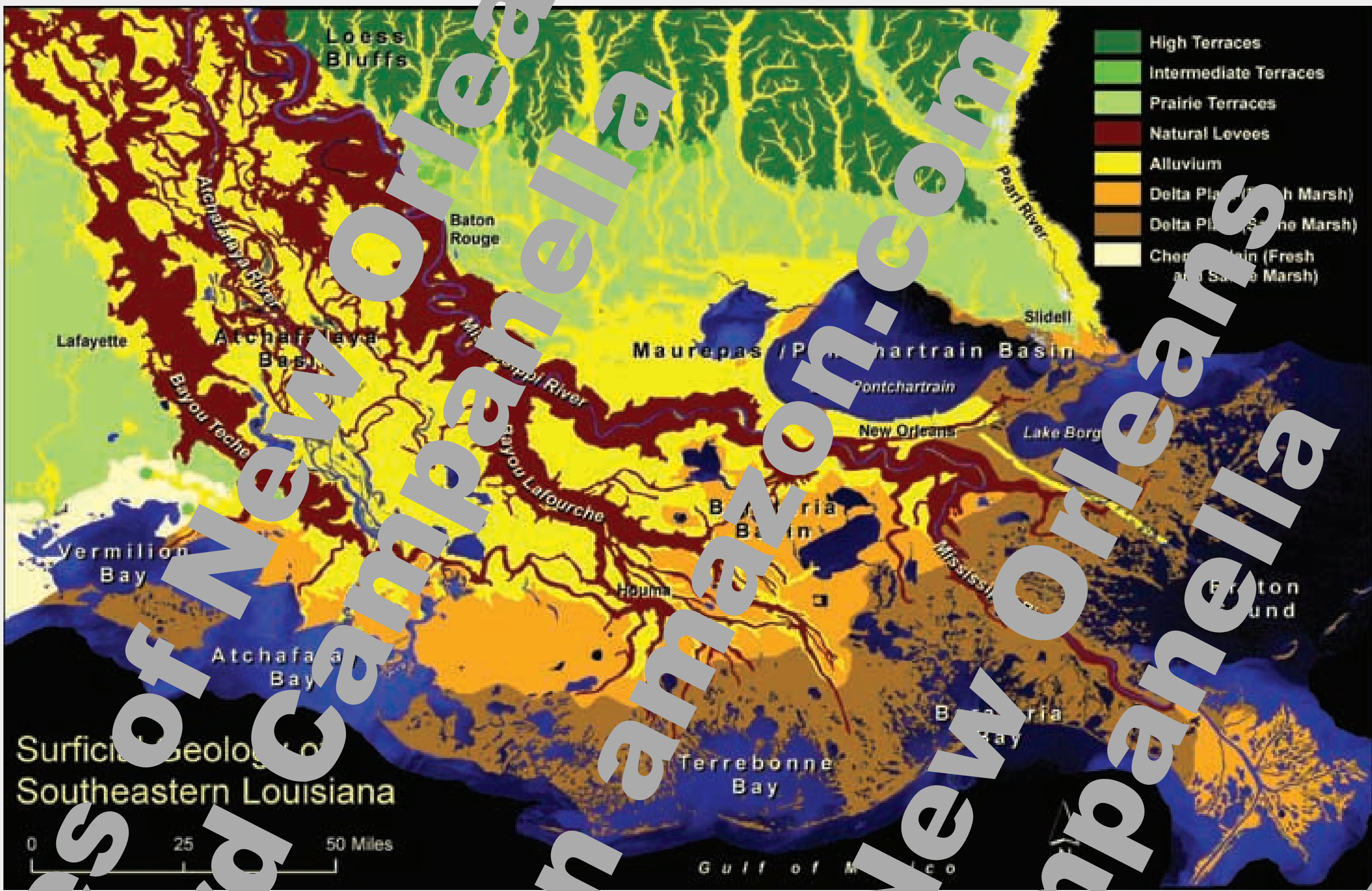
Name of Delta Complexes	Years Ago	General Location
Outer Shoal Delta Complex	Possibly 9,000-8,000	Relict shoreline now submerged in Gulf of Mexico south of Terrebonne Parish
Maringouin Complex*	7,300-6,200, possibly earlier	Expansive delta reaching fifty miles off present-day coast of south central Louisiana
Teche Complex*	6,000-3,500	Smaller complex in the Vermilion Bay-Morgan City area

[13] Saucier, *Geomorphology and Quaternary Geologic*, 1:276.

St. Bernard Complex*	4,300-1000	Elongated complex from Baton Rouge area east to Mississippi Sound, including New Orleans region, where it built historically significant topographic features.
Lafourche Complex*	3,500 to 100	Large, circular complex straddling Bayou Lafourche distributary; mostly terminated when bayou was sealed off from river in 1904.
Plaquemines Complex*	1,100 to present	From English Turn to present-day “birdfoot;” also called Balize or Modern Delta.
Atchafalaya Complex	300 to present	Recent distributary delta (only one from modern times) at mouth of Atchafalaya River. Enlarged by increasing quantities of Mississippi water until Old River Control Structure (1963) stabilized flow.
Based on research by D.E. Frazier, “Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology,” *Transactions of the Gulf Coast Association of Geological Societies* 17 (1967): 287-315 (marked by *), and others, as reviewed by Roger T. Saucier, *Geomorphology and Quaternary Geologic History of the Lower Mississippi Valley*, 2 vols. (Vicksburg, MS, 1994), 1:141, 255, 276-86.		

According to Frazier's assessment, the New Orleans region is mostly a product of the St. Bernard and Plaquemines deltaic complexes, starting at least 4,300 years ago—a time frame which agrees with earlier research. The soil, topographical, and hydrological features formed by those complexes would profoundly affect the historical geography of New Orleans, and are discussed in detail in the following chapters and referenced throughout this book.

New Orleans, then, stands not on ancient, solid North America, but on a thin, soft alluvial “deposit” cast recently out upon the continent's margin. Not only is New Orleans' underlying terrain the youngest of any major American city, but southeastern Louisiana is the youngest region of its size in the nation, and the entire lower Mississippi Valley, from Cairo to the sea, comprises the continent's youngest surface soils. By the time of French exploration, around 1700, most of the landscape of southeast Louisiana and New Orleans had reached a stage recognizable today. The passes, bays, bayous, lakes, natural levees and backswamps which currently grace our maps with colonial-era names were in place and known well by the Native Americans, and later greatly valued by the likes of Iberville and Bienville. But these features, at the dawn of the colonial era, were still geologically alive and shifting, still obeying no law but gravity, still controlled only by the forces of nature. The Mississippi River periodically swelled over its banks and replenished the backswamp with new sediments; enough river water still flowed toward the old Lafourche Delta to inspire Iberville to name it “the fork” and the Bayou Manchac distributary still injected fresh muddy river water into the region once similarly nourished by the old St. Bernard Delta. Over the next 300 years, man would seize this malleable geology and re-form it to improve the safety and circumstances for the time frame in which he lives: the moment and the immediate future. Today, artificial levees ensure that the river no longer overflows; the distributaries are sealed off for similar reasons; the backswamps are drained and scored with canals; and the Mississippi is controlled by the Old River Control Structure from seizing the steeper gradient to the sea via the Atchafalaya River. Here, like few other places in the world, man has intervened in geological processes and wrested control of them, allowing New Orleans to grow and prosper with far fewer natural disasters than uncontrolled nature might have wrought. The long-term consequences of this intervention, however, are perfectly bleak. But more on this later. For now, suffice it to say that the major natural geological processes which formed the New Orleans region are on hiatus, currently controlled by the hands of man. Their resumption is not a question of *if* but *when*, and we can only ponder what 30° North, 90° West will look like then.



Surficial geology of southeastern Louisiana, compared to satellite image of same area. Map by author based on data prepared by Louisiana Geological Survey and LSU Geography and Anthropology/CADGIS Lab.

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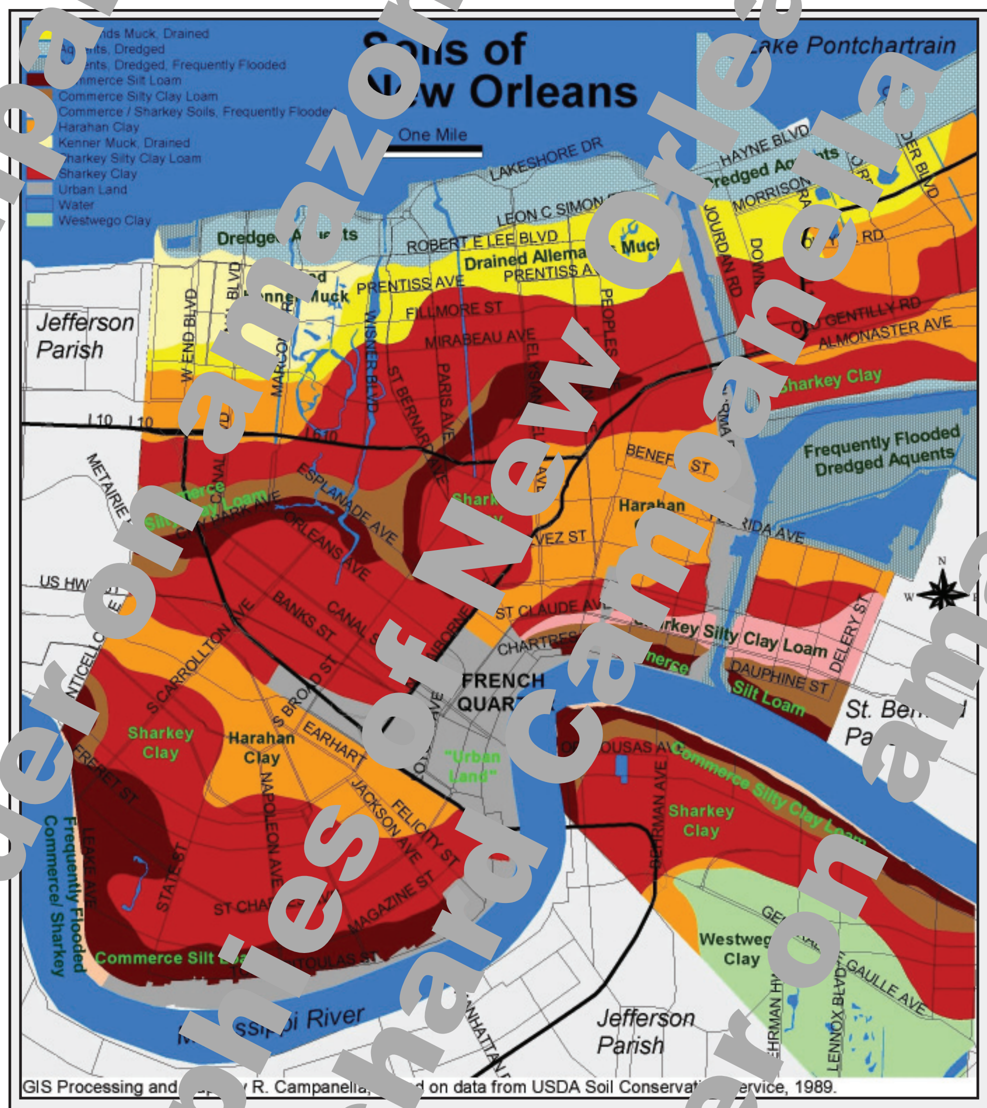
Pedological New Orleans

Gentilly muck. Westwego Clay. Sticky gumbo.[14] Terms like these are used by pedologists[15] to describe the soils of New Orleans, which, like many phenomena here, are exceptional to the national norm and influential, a sort of stealth factor, to the development of the city. New Orleans' soils are salient for a number of reasons. First, like the human population, every particle here is an "immigrant" to this deltaic plain, arriving episodically over five millennia and as recently as the mid-nineteenth century, not to mention those imported artificially today. Second, given the wide range of soil types and classes found across North America, these soils are drawn entirely from one extreme: the very finest sediments settled here. Third, considering the many human uses of soil, from agriculture to urbanization, New Orleans' soils again occupy the extremes. They (or rather about half of them) are outstanding for cultivation, but outstandingly poor for urban development (especially the *other* half). Fourth, soils here render inadequate the narrowest definition of soil—"weathered material at the Earth's surface"—in favor of a broader interpretation: "a natural body composed of minerals, organic compounds, living organisms, air and water in interactive combination, produced by physical, chemical and biological processes."[16] Finally, humans in New Orleans have both adapted to and altered the soils of the region—deltaic soils are more vulnerable to transformation with even minor intervention—such that Crescent City soils today are a product of both nature and man.



Soil Formation

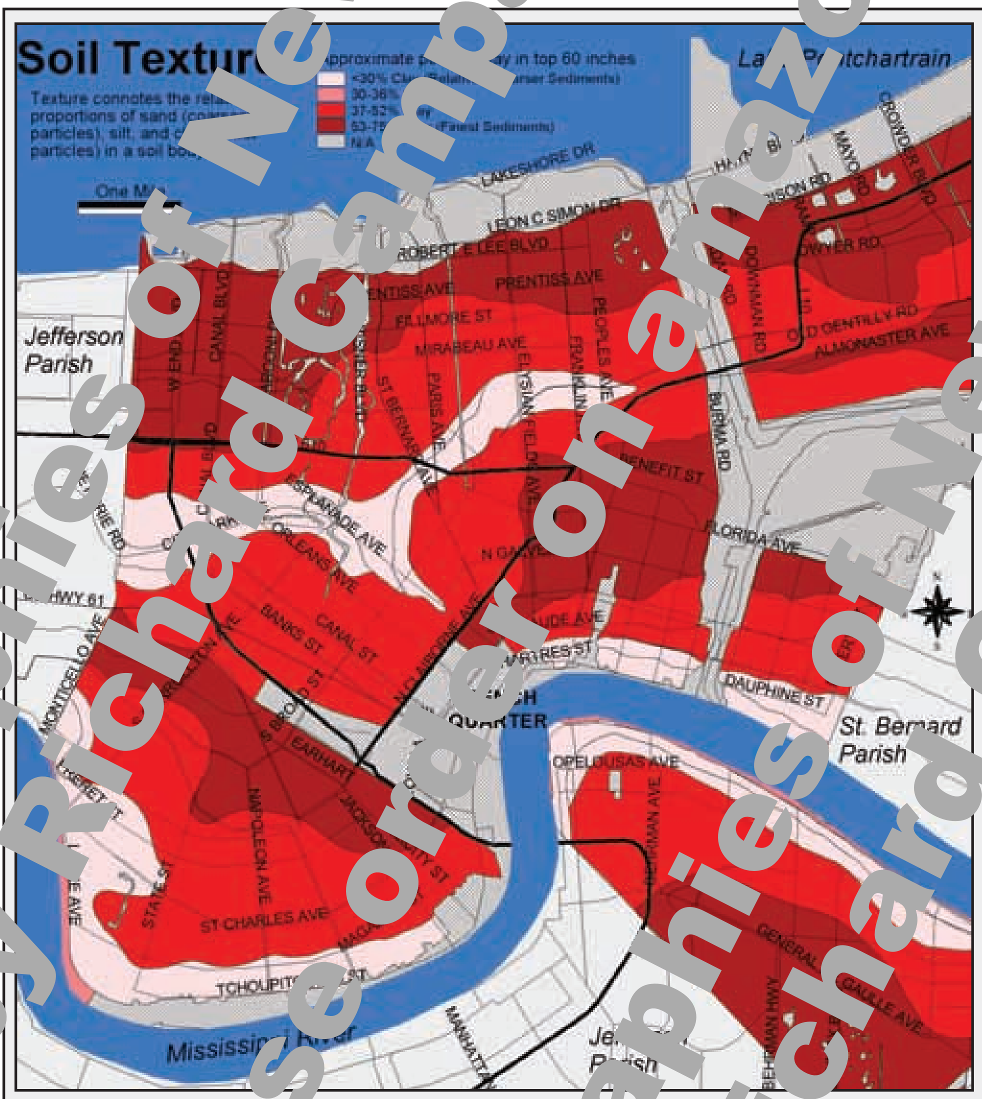
Every natural soil particle on or near New Orleans' land surface is a recent import to the region, originating anywhere from New York to New Mexico, from Alberta to Alabama, delivered to the Crescent City by the Mississippi River and its tributaries within the past few thousand years. The particles, as they start their journey, erode from parent material by water, ice, wind, or chemical reaction, and, depending on their region and route, vary greatly in composition and size. A few exceed 75 mm in diameter (stones) and tumble with the current in the uppermost tributaries of the Mississippi, such as the Yellowstone River in the Wyoming Rockies or the Mississippi headwaters in the forests of Minnesota. Other particles measure 75 mm to 2.0 mm in size, called gravel, and owing to their lighter weight, make it down the Missouri, Ohio, or main channel of the Mississippi. Far more particles measure between 2.0 mm and 0.05 mm, and are known respectively as very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. Sand makes it as far downriver as the delta, though it mostly settles as bedload farther upriver and mobilizes during high springtime flow. Silt, measuring 0.05 mm to 0.002 mm, and clay—the finest particles, less than 0.002 mm in diameter—dominate the sediments borne by the lowest stretches of the Mississippi, and spill out upon gulf waters and the Continental Shelf in vast quantities. Only the finest, lightest sediment particles survive the pull of gravity and make it to the New Orleans region, which stands 96 percent of the way down the 2,340-mile Mississippi River. Any particle in southeastern Louisiana coarser than a few millimeters in diameter was imported by humans. "An alluvial soil cannot be supposed to abound in rock," wrote Maj. Amos

[14] Works Progress Administration, *Some Data in Regard to Foundations in New Orleans and Vicinity* (New Orleans, 1937), 104.

[15] Derived from the Greek *pedon* (meaning ground, base, soil, earth), the term *pedology* can mean both the study of child development and education, or the scientific study of soils.

[16] John Gerrard, *Fundamentals of Soils* (London and New York, 2000), 1.

Stoddard in his 1812 description of Louisiana, "neither on the island of Orleans, nor along the immense flat country on the west side of the Mississippi…is even a single pebble to be found."[17] So devoid is the city of stones that the New Orleans Geological Society's walking tour of downtown is devoted entirely to the building stones used in prominent edifices, quarried "from scores of places around the world" and bearing "interesting stories to tell anyone willing to listen."[18] The sediment particles beneath those edifices testify to the sheer magnitude of the Mississippi River system, and to New Orleans' position at its extreme terminus. They too have interesting stories to tell.



When, historically, the Mississippi seasonally overflowed its banks, the cresting water carried only the finer, lighter portion of that already well-sieved selection of sediment onto the land surface. These particles did not settle evenly, but were sorted by gravity according to their size. The coarsest particles settled first, immediately after the water spilled beyond its channel and suddenly slowed its speed upon the land. First in line for sediment deposition from floods of any size, these "natural levees" built up fastest and are now the highest and best-drained features in the deltaic plain. Natural levees in New Orleans comprise varying amounts of sand, lots of silt, and some clay; while they are not predominantly sand, they are *sandier* than most other regional soils. As floodwaters flowed backward off the natural levee, finer particles traveled with them until they too settled, anywhere from a few score to a few thousand feet from the river. Their deposition formed the backslope of the natural levee, comprising almost no sand, a fair portion of clay, and large quantities of silt. Most clay particles, finest in diameter and lightest in weight, generally settled when the floodwaters had run their course and accumulated in lowest spots farthest from the river: the backswamp.

Soil Transformation

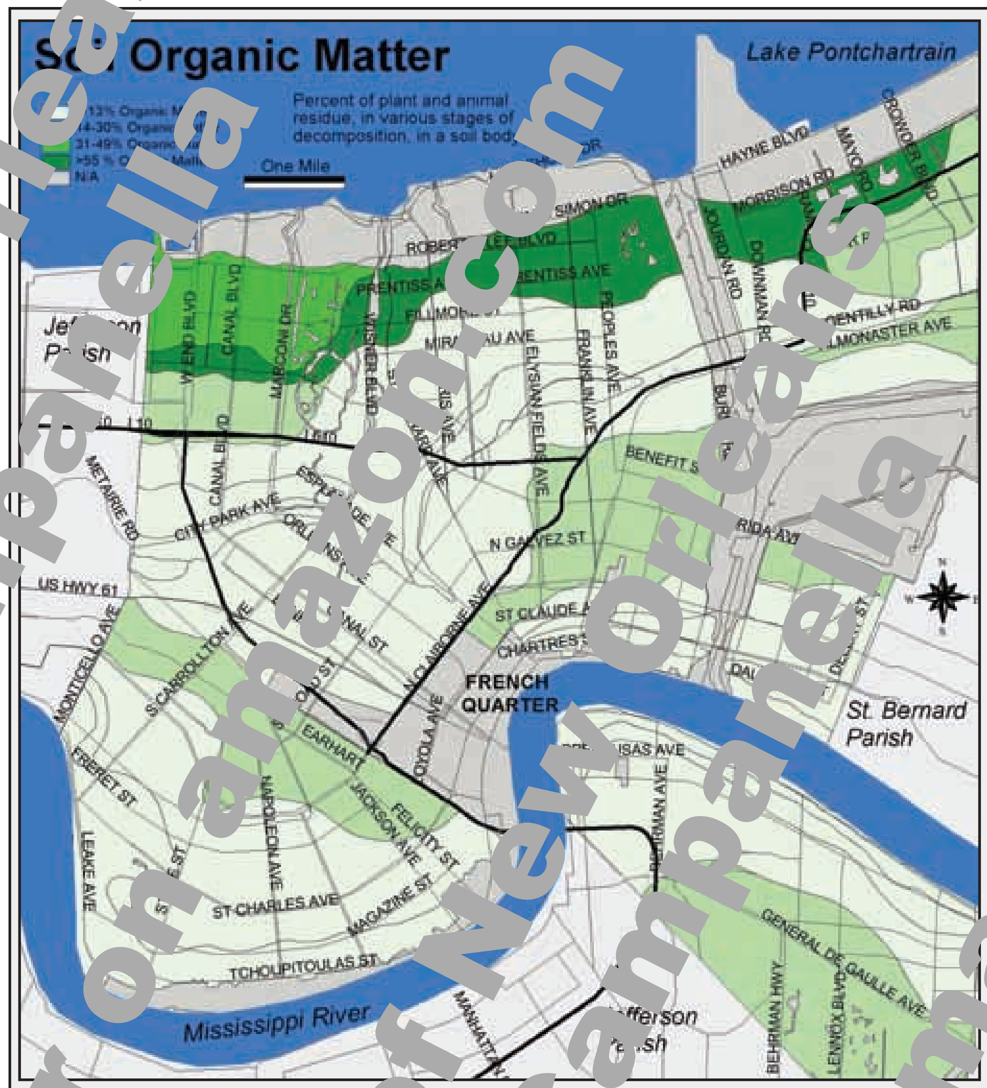
Gravity, then, determines which particles reach the deltaic plain, which spill over the river banks during floods, and how they settle topographically once deposited upon the land surface. The assorted sediments then undergo processes of formation and transformation, rendering them truly local and unique to the region. Five factors guide these ongoing processes:[19]

Climate — New Orleans' brief, mild winters and long, hot summers accelerate soil transformation primarily by speeding the decomposition of vegetation. The region's semitropical levels of humidity and rainfall saturate its soils, though not all areas are saturated equally (see Topography, below) nor react the same (see Organisms, below).

Organisms — Living organisms alter soils by changing their structure, porosity, and, ultimately, composition. Plants cycle nutrients from lower layers to the surface, while their roots stir and exchange layers. Most significantly, when they die, their organic matter is decomposed by other organisms—bacteria, fungi, animals—integrating it back into the soil to be mixed and cycled by other plants. Soils rich in organic matter predominate where water accumulates (see Topography) and saturates (see Particles). Organic matter buried in New Orleans soils may range from dead leaves and grasses to enormous cypress trunks and stumps—some mysteriously cut, as if by a saw, lying twenty to thirty feet below street level.[20] So thick were

[17] Major Amos Stoddard, *Sketches, Historical and Descriptive of Louisiana* (Philadelphia, PA, 1812), 175.
[18] Edward S. Slagle, *A Tour Guide of the Building Stones of New Orleans* (New Orleans, 1982), 1.
[19] Larry J. Trahan, *Soil Survey of Orleans Parish, Louisiana* (Washington, DC, 1989), 55-57.
[20] Works Progress Administration, *Some Data in Regard to Foundations in New Orleans and Vicinity* [illegible] 3.

layers of buried trees when the foundations for the gas works were excavated in the 1830s and 1840s, contractors had to replace their Irish ditch-diggers with 150 "well-practised axe-men from Kentucky"[21] to chop through what they calculated to be eight centuries' worth of cypress timber.



Particles — The parent material from which sediments eroded affects the mineralogy, chemistry, color, and other aspects of local soils. Equally significant is the soil's "texture," that is, its varying percentages of gradations of sand, silt, and clay. In general, the coarser the texture of soils (mostly sand, some silt, little clay), the more air spaces among the particles, allowing water to filter through, which in turn allows organic matter to decompose fast. The finer the texture (mostly clay, some silt, little sand), the fewer the pockets, forcing water to accumulate on top as it slowly (if at all) percolates through. Puddled water prevents "the complete oxidation and decomposition of the plant residue,"[22] leaving clayey soils rich in both water and organic matter.

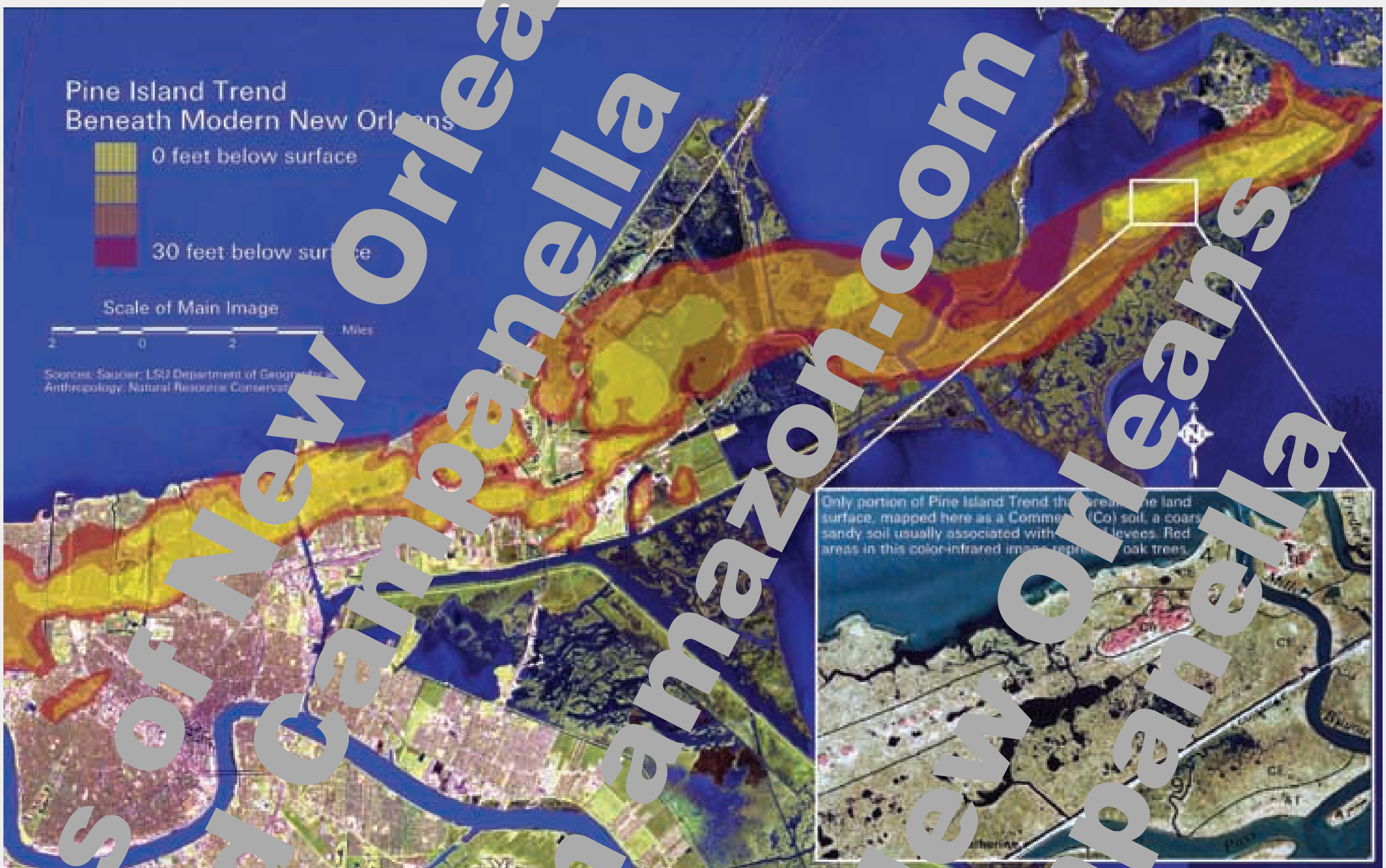
Topography — The lay and shape of the land directs the flow of rainfall and floodwater from the higher, coarser-grained soils of the natural levee toward the lower, finer-grained soils of the backswamp, where they accumulate as marshes, swamps, or back bays. In doing so, topography sorts particle sizes and plays a role in its own destiny. Explained Major Stoddard in 1812,

> That the banks of the river are much more elevated than the circumjacent country…is occasioned by a more copious deposition along the margins, than at a distance from them. These are thickly covered with grass, and a vast variety of ligneous plants, which serve to filtrate the waters in their progress to the low grounds and swamps…. Hence the lands along the banks…are excellent for tillage; while the whole surface in the rear of them, extending to the sea, is alternately covered by lakes and impassable swamps.[23]

Time — The temporal factor in soil formation allows the above factors to take effect, eventually producing soil "horizons," or layers, of distinct characteristics. Not enough time has elapsed in deltaic New Orleans for distinct horizons to develop, with the exception of the natural levees, which have weakly developed "A" and "B" horizons. But this is not to say that the soils of New Orleans are not stratified: dozens of strata, ranging from clays of various colors to sands of different mixtures to water, humus, and stumps, comprise profiles one hundred to two hundred feet deep throughout the city.[24] Additionally, nearly three hundred years of human occupation have added artificial fill to the strata, creating a historical-geological profile dramatically visible to pedestrians whenever French Quarter streets are opened up for sewer work. There, beneath the asphalt, lies a layer or two of recent concrete, followed by one of early twentieth-century paving stones, then by increasingly intriguing layers of massive old bricks and ancient orange-colored brick fragments, dating to the nineteenth and eighteenth centuries. When the foundation for Charity Hospital was excavated in the 1930s, the underlying strata limned a timeline of local human and geological history:

> The light upper stratum is artificial filling, such as earth, cinders, brick, etc., and extends to a depth of about 4 feet. The second stratum is about 6 feet thick and is almost pure river silt, evidently deposited many years ago by overflow from the Mississippi River. The third stratum is about 8 or 10 feet thick and can be distinguished by its dark color…composed almost entirely of leaves, roots, and humus…. Below this is river

[21] Sir Charles Lyell, *A Second Visit to the United States of North America*, 2 vols. (London and England, 1850), 2:136-37.
[22] Trahan, *Soil Survey of Orleans Parish, Louisiana*, 56.
[23] Stoddard, *Sketches, Historical and Descriptive, of Louisiana*, 159.
[24] Works Progress Administration, *Some Data in Regard to Foundations in New Orleans and Vicinity*, 22-45.



The Pine Island Trend, a buried barrier island, may have influenced the routes of distributaries of the Mississippi (and perhaps the river itself) as they first flowed through the area. Its compacted sands offer a stable foundation for large engineering projects such as Interstate 10, which follows the trend in eastern New Orleans. In certain low-lying lakeside neighborhoods, the relict feature comes close to the topographic surface, and sometimes even breaks it. One extraordinary example, arguably the only part of New Orleans' natural land surface not formed by the Mississippi River (but rather by the Pearl), is part of a series of oak-covered "islands" (inset) with a long history of aboriginal use. *Map and GIS processing by author based on data from Saucier, LSU Geography and Anthropology, and Natural Resource Conservation Service.*

> silt again, and at about 18 to 20 feet below ground surface… ground water or permanent line of saturation is reached.[25]

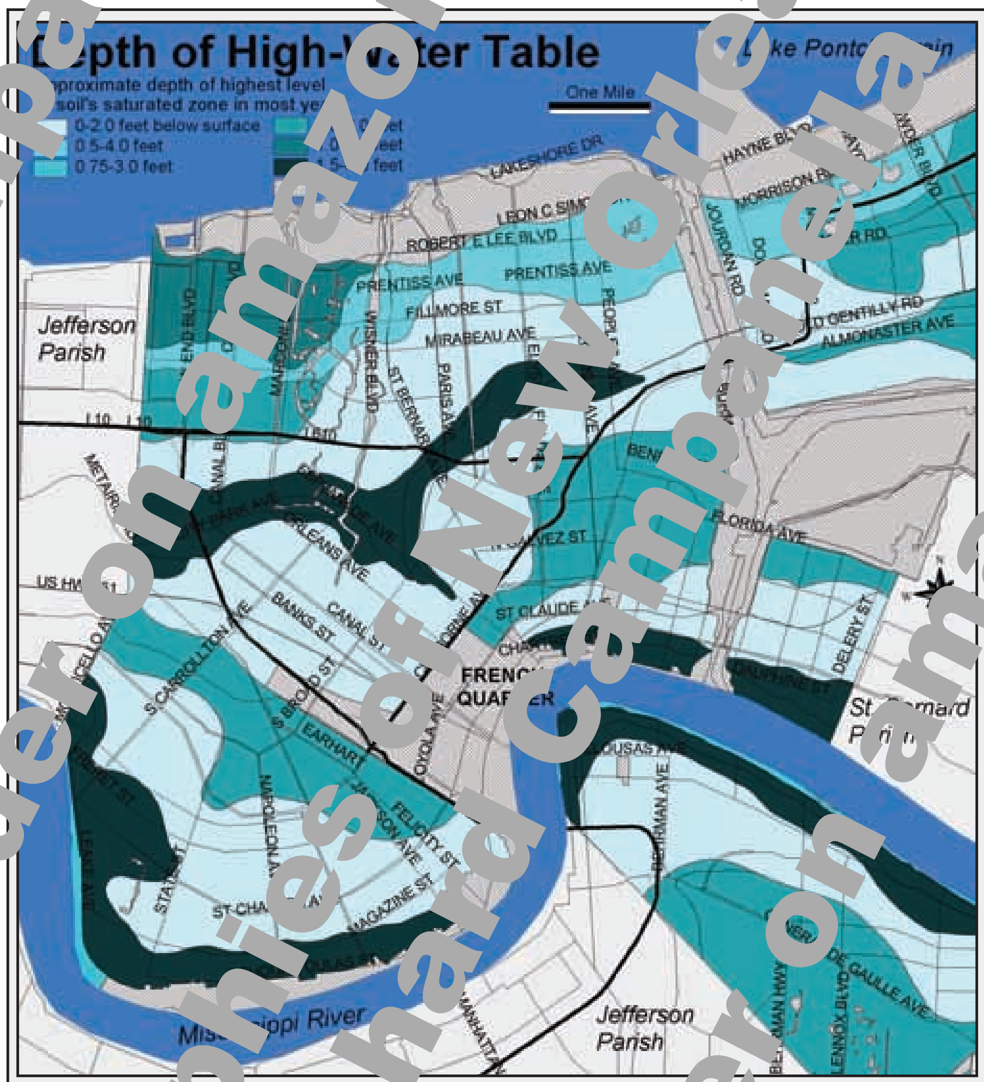
New Soils Environment

Consider, then, how man has altered New Orleans' soil. First and foremost, he has artificially augmented the natural levees of the Mississippi River and severed the river's distributaries, depriving the landscape of replenishing sediments in exchange for protection from floods. New Orleans has not been significantly dousted by new riverine sediments since the days of the last levee crevasses, well over a century ago. Man has also altered the hydrology of the region by draining the backswamp soils of their water content and clearing their forest and marshes, which eliminated organic matter from the surface and from soil-transformation processes, allowing soils to compact and subside. To counter the shrinkage, man has imported foreign soils, fill, shells, riprap, gravel and rocks to the landscape, building up some areas and excavating others for canals and drainage. He has also dredged material from Lake Pontchartrain and appended them to the lakefront and man-made navigational canals. He has introduced, accidentally and intentionally, biota not native to these environs, from fire ants to Formosan termites to water hyacinth to banana trees, all of which ultimately affect soils. Finally, he has paved over natural soil surfaces, severing them from the atmosphere while concentrating runoff into man-made drainage systems. As a result, the soil composition of Orleans Parish's 127,000 terrestrial acres has been significantly altered by anthropogenic activity, primarily through flood control, drainage, deforestation, and paving. Man has created a new soils environment in New Orleans, a massive transformation often overlooked for his more visible impacts on the skyline, the river, and the coast. This alteration of the natural environment is, of course, essentially integral to any city. The deleterious affects of these actions (primarily subsidence and erosion), and the challenge of eliminating or at least minimizing them, are the expected societal costs that necessarily accompany the benefits of urbanization.

Europeans started altering soil processes with the clearing of the Bayou St. John area (1708), French Quarter site (1718), erection of the first levees (1719), and continuing thenceforth. But aboriginal populations also played an earlier role in transforming soils, albeit on a drastically smaller scale. One example involves a series of Tchefuncte Indian sites in the marshes of eastern Orleans Parish, known as Little Woods,

[25] Ibid., 10 of 1939 addendum.

Little Oak, and Big Oak Island. Structurally, these sites are mounds of *Rangia* clamshells, bone, and other debris; functionally, they probably served as ceremonial sites, living spaces, or middens (refuse heaps), dating from roughly 500 B.C. to 200 A.D., when they were much closer to the Lake Pontchartrain shore. The relationship between these archeological sites and the underlying Pine Island Trend is unclear; perhaps they were modifications of the crest of this ancient barrier island. Geological maps depict the subterranean Pine Island Trend as just barely breaking the surface of the earth near the archeological sites, like the ridged back of an alligator emerging from swampwater.[26] As high as fifteen feet above the marshes and hundreds of feet long, these "islands" have been periodically occupied by Natives, hunters, and trappers, practically into modern times. "These midden deposits accumulated over different time spans, some long, and some short; some mounds were purposeful and some were not, but all had one common result: vertical buildup of sites above sea level," wrote archeologist T.R. Kidder. As a result, these early man-influenced soils were better drained and fostered the growth of vegetation normally associated with natural levees, such as oaks, cypress, hackberry, and willow. "The planned and unplanned shell accumulation formed an entirely new ecozone in the marsh;"[27] which, coupled with a new hydrology, further transformed the soil. Today, these sites, currently under excavation by the University of New Orleans, form pedological aberrations in the sea-level muck, saline marshes, and brackish water of eastern Orleans Parish. A 1989 soil survey by the Department of Agriculture designated Big Oak Island as a Commerce silty clay loam, a natural-levee soil as out-of-place in the eastern marshes as an iceberg in the Gulf of Mexico.



Soils of New Orleans

One early effort to map the soils of the New Orleans region was conducted in 1903 by Thomas D. Rice and Lewis Griswold of the Department of Agriculture's now-defunct Bureau of Soils. The map, produced at a scale of one inch to one mile (1:62,500), shows highly generalized soil patterns categorized into now-antiquated classes of Yazoo sandy loam (river's natural levees), Yazoo loam (distributaries' natural levees), Yazoo clay (backslopes of natural levees), Sharkey clay (backswamps), and muck (lakeside marshes).[28] Much more detailed efforts were made by the department's Soil Conservation Service, culminating with a 1:20,000 survey and analysis, the *Soil Survey of Orleans Parish, Louisiana*, researched in 1986 and published in 1989. Like most soils maps, the 1989 survey depicts soil pods within the urbanized area as discrete polygons with hard edges in precise locations. Of course, soils form no such clear-cut spatial units; their characteristics change gradually, and their components vary slightly in their relative proportions, as one moves across the landscape. Pedologists extract soil samples in a systematic fashion, analyze them, and judge where one soil class transitions to another, a process that involves some subjective judgment and may be better cartographically as a "fuzzy" border rather than a hard line. The following descriptions of New Orleans

[26] Roger T. Saucier, *Geomorphology and Quaternary Geologic History of the Lower Mississippi Valley*, 2 vols. (Vicksburg, MS, 1994), 1:25.

[27] Tristram R. Kidder, "Making the City Inevitable: Native Americans and the Geography of New Orleans," in *Transforming New Orleans and Its Environs: Centuries of Change*, ed. Craig E. Colton (Pittsburgh, PA, 2000), 13.

[28] Thomas D. Rice and Lewis Griswold, *Soil Map, Louisiana, New Orleans Sheet* (Louisiana Agricultural Experiment Station, 1903) (probably issued in conjunction with the 1904 *Soil Survey of the New Orleans Area, Louisiana*); The Historic New Orleans Collection, accession number 1988.145.

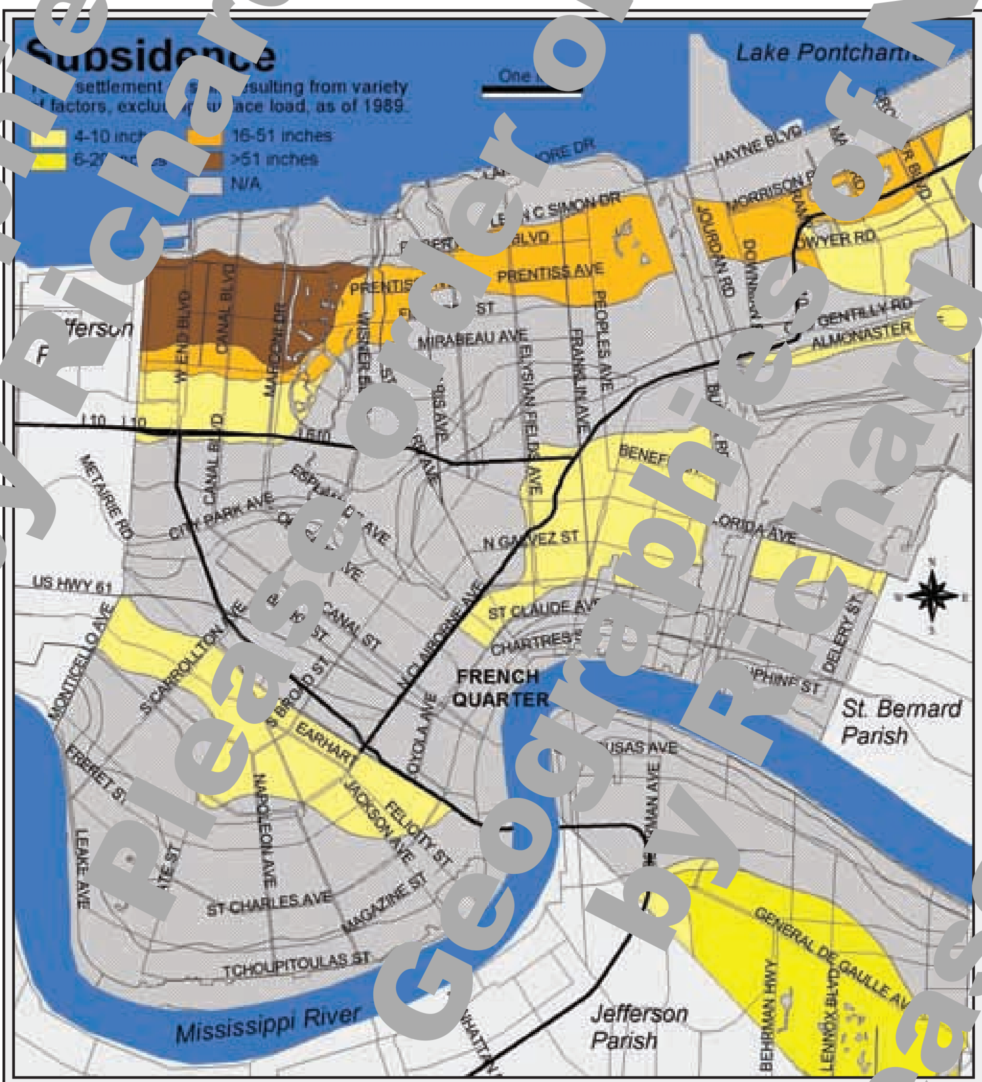
soil types, listed in order of historical influence, are drawn from this 1989 survey.[29]

Commerce Silt Loam (4,560 acres; [illegible] percent of terrestrial Orleans Parish)
Characteristics: A relatively well-defined soil comprising roughly equal parts of sand, silt, and clay, with little organic content. This dark, fertile soil is found exclusively on high natural levees.
Range: Historic neighborhoods on the crest of natural levees of Mississippi River and distributaries, including riverside portions of uptown to CBD to French Quarter to Holy Cross; Algiers Point to Lower Coast; City Park Avenue to Bayou St. John/Fairgrounds; Gentilly Boulevard and portions of Esplanade Ridge.
Historical Influences: Highest historical influence: excellent for plantation agriculture and pasture; best locally available soil for urban development. Historic New Orleans and its adjacent plantations were largely based upon these soils.
Anthropogenic Change: Originally forested, these soils have been mostly cleared since the early eighteenth century and fully urbanized since the late nineteenth century. Lower Coast of Algiers and live oak grove in lower City Park represent last forested portions of this valuable soil.

Commerce Silty Clay Loam (2,153 acres; 1.7 percent)
Characteristics: This dark, fertile soil is a slightly finer-textured variation of Commerce silt loam, found on the backslope of the natural levees of the river and the old Metairie/Gentilly distributaries.
Range: Carrollton, lower City Park, parts of Gentilly and Esplanade Ridge, rear of French Quarter to Holy Cross, Algiers and Lower Coast, plus Big Oak Island and other archeological sites in eastern marshes.
Historical Influences: High historical influence: very good for agriculture, relatively sound for urban development, compared to alternatives.
Anthropogenic Change: Cleared of their original forest and mostly urbanized.

Sharkey Silty Clay Loam (1,00[illegible] acres; 0.8 percent)
Characteristics: Finer in texture than the Commerce series, this dark, fertile soil is found on the rear backslope of some river natural levees, and on the crest of meager natural levees on small waterways.
Range: Portions of French Quarter through St. Roch and Bywater to Lower Ninth Ward; minor natural levees following Bayou Sauvage and Turtle Bayou in eastern marsh.
Historical Influences: Historically significant: these soils lined the former "back-of-town," where the city interfaced with swamps. Good for agriculture and fair for urban development (relatively speaking), though less so on both accounts than Commerce series.
Anthropogenic Change: Pods in downtown are now fully urbanized, but small pods in the eastern marshes remain close to their original state.

Sharkey Clay (22,549 acres; 17.7 percent)
Characteristics: This soil is a slightly finer-textured variation of Sharkey silty clay loam, found in a much more expansive distribution.
Range: Covers extreme rear of natural levees and into former backswamp throughout heart of city; extends through Gentilly Boulevard to Bayou Sauvage as well as Lower Coast of Algiers.
Historical Influences: Historically influential, forming middle and rear sections of most antebellum sugar planta-



[29] Excluded from this list are "Urban Lands" (2,287 acres; 1.8 percent of parish), which are highly developed Commerce, Sharkey, and Harahan soils, and "Dumps" (389 acres, or 0.2 percent).

tions, but not urbanized until late nineteenth century and afterwards.

Anthropogenic Change: Almost all zones with exception of Bayou Sauvage have been deforested, drained, and developed; most experience varying levels of subsidence.

Frequently Flooded Commerce and Sharkey Soils (602 acres; 0.5 percent)

Characteristics: Mix of sediments deposited by river on the batture, sometimes comprising significant amounts of coarse sand particles as well as driftwood and debris. Frequently flooded depending on stage of river.

Range: Battures along riverside of Carrollton, Audubon Park, McDonogh, Algiers Point, and along Lower Coast of Algiers to Twelve Mile Point (English Turn).

Historical Influences: Historically important, but for unusual reasons: these batture soils accumulated riverside of Tchoupitoulas, from Jackson Avenue to St. Peter Street, during early nineteenth century, allowing humans to incorporate them into the urbanized area. Today, this soil type is limited to narrow battures strewn out along immediate riverbank.

Anthropogenic Change: These soils are among the last examples of natural sediment deposition in New Orleans, due to their unprotected riverside locations. They are often forested with willow trees. Older pods have since been developed by urban development (example: Warehouse District).

Harahan Clay (13,347 acres; 10.5 percent)

Characteristics: A gray-to-black colored clay found in formerly forested backswamps, where backslopes of natural levees fall below sea level. This clay is finer in texture, higher in organic matter, poorly drained, and less adequate for agriculture and development than all Commerce and Sharkey soils.

Range: Sections of Lakeview and City Park, Hollygrove to Broadmoor, Central City and rear of CBD, Tremé through St. Claude to Lower Ninth Ward; Lake Forest East and other eastern subdivisions; parts of Algiers.

Historical Influences: Less historical influence: this backswamp soil made up areas at or beyond the rear edge of long-lot plantations, and were not urbanized until the early twentieth century, after the drainage system was installed.

Anthropogenic Change: Mostly cleared of forest, drained, filled in, and paved over. Some Harahan clays are still forested, particularly along Mississippi River-Gulf Outlet Canal.

Drained Kenner Muck (4,446 acres; 3.5 percent)

Characteristics: Similar to Harahan Clay, but associated with freshwater marshes rather than dense, forested swamps, and even less suitable for agriculture and urban development.

Range: Low-lying lakeside areas in northern half of Lakeview and City Park, and in the expansive, semi-forested eastern marshes east and north of Michoud.

Historical Influences: Little historical significance. These soils comprised the Lake Pontchartrain shore prior to the 1920s Lakefront land reclamation project.

Anthropogenic Change: Developed areas are highly altered by drainage, Lakefront levees, fill, and residential urbanization; undeveloped areas are close to their natural state.

Clovelly Muck ([illegible]6,175 acres; 20.6 percent)

Characteristics: Very fluid, mucky clay soil with high quantities of organic material and saline water, found in thousands of acres of mostly undeveloped brackish marsh.

Range: Eastern marshes along the Intracoastal Waterway, Chef Menteur Pass and Rigolets, on Point aux Herbes peninsula, along Lake Borgne shore near Bayou Bienvenue outlet.

Historical Influences: Little historical influence.

Anthropogenic Change: Still bear their natural vegetative cover, but often subject to erosion, increasing salinity, and non-native plants.

Lafitte Muck (19,22[illegible] acres; 15.1 percent)

Characteristics: Similar to Kenner and Clovelly mucks; generally associated with saline marshes.

Range: Eastern marshlands, particularly Point aux Herbes peninsula, Chef Menteur Pass, Bayou Bienvenue area, and Lake Borgne shore.

Historical Influences: Little historical significance.

Anthropogenic Change: Mostly in their natural state, but highly prone to erosion and increasing salinity.

Dredged Aquents (7,[illegible] acres; 5.9 percent)

Characteristics: Dredged material from adjacent lakes and waterways, deposited to build land or excavating navigation canals. Some areas are developed with residential neighborhoods; others are undeveloped.

Range: Found along Lakefront, from West End to Haynes Boulevard; Jourdan Road Terminal and along MR-GO; Irish Bayou/Point aux Herbes; Michoud area; Venetian Isles, Bayou Sauvage and parts of Rigolets.

Historical Influences: No historical influence, beyond that of specific engineering projects.

Anthropogenic Change: Entirely a product of anthropogenic activity.

Frequently Flooded Dredged Aquents (8,148 acres; 6.4 percent)

Characteristics: Same as dredged aquents, except more flood-prone for their proximity to waterbodies. Often strewn with clam and oyster shells.

Range: Found at the interface of man-made lands with adjoining water bodies: West End Park, Lakeshore Drive along lakefront, former Pontchartrain Beach, land paralleling Industrial Canal, MR-GO, and Intracoastal Waterway; also Michoud, Venetian Isles and Point aux Herbes.

Historical Influences: No historical influence.

Anthropogenic Change: Entirely a product of anthropogenic activity.

Drained Allemands Muck (5,885 acres; 4.6 percent)
Characteristics: A clay soil with high organic and water content, found in low-lying former freshwater marshes lakeside of the Metairie/Gentilly Ridge.
Range: Lakeside neighborhoods and eastern marshes: Harrison Avenue corridor through West End and Lakeview, across central City Park, through Filmore, St. Anthony, Milneburg, Pontchartrain Park, Lake Kenilworth, and Lake Forest East; also in eastern marshes near Michoud.
Historical Influences: Little historical influence: too wet and fine-grained for plantation agriculture; too flood-prone for urban development, until the twentieth century.
Anthropogenic Change: Municipal drainage system opened up these soils to urbanization; drained areas now often covered with one to three feet of artificial fill. Urbanized pods are susceptible to subsidence; undeveloped pods in eastern marshes are prone to salt-water intrusion and erosion.

Westwego Clay (4,930 acres; 3.9 percent)
Characteristics: Dark gray clay found in former and present-day swamps, with a fair amount of organic matter.
Range: South Point area of Point aux Herbes peninsula; Behrman, Brechtel, and Old Aurora neighborhoods on the west bank.
Historical Influences: Historically unimportant.
Anthropogenic Change: Cleared, drained, and suburbanized on the West Bank; still in natural state in eastern marshes.

Gentilly Muck (4,148 acres; 3.3 percent)
Characteristics: A dark, fluid, mucky clay found in brackish marshes, almost continuously flooded.
Range: Throughout eastern marshes, particularly paralleling slow-moving bayous, inlets, and lake shores.
Historical Influences: No historical significance.
Anthropogenic Change: Still bears natural vegetative cover, but often subject to erosion and increasing salinity.

From the above soil classes, the following "superlatives" may be identified for New Orleans soils:
Best Soil to Build Upon: Commerce soils (superior only when compared to the local alternatives).
Best Soil to Farm: Commerce and Sharkey series: fertile, well drained, and well textured.
Worst Soils to Farm or Build Upon: Gentilly, Clovelly, and Lafitte mucks: flooded, clayey, and saline.
Youngest Soils: Frequently flooded Commerce/Sharkey soils deposited by the river along the batture.
Highest Soils: Commerce silt loam, on the crest of the natural levee.
Lowest Soils: Harahan clay, in the drained and subsiding marshes near the Lake Pontchartrain shore.
Coarsest Soils: Frequently flooded Commerce/Sharkey soils, in batture areas, containing the most sand.
Finest Soils: Gentilly, Clovelly, and Lafitte mucks, farthest from the river and comprising the most clay.
Most Saline Soil: Lafitte muck, near the brackish water lakes.
Most Organic Soil: Allemands muck, in the backswamp.
Most Vulnerable to Subsidence: Kenner and Lafitte muck in theory; aquents according to field data (average of 5.9 millimeters per year subsidence).[30]
Highest Water Table: Gentilly, Clovelly, and Lafitte mucks.
Most Common Soil in Orleans Parish: Clovelly muck.
Rarest Natural Soil in Orleans Parish: Frequently flooded Commerce/Sharkey soils (batture soils).
Soils Currently Closest to Prehistoric State: Gentilly, Clovelly, and Lafitte mucks.
Most Altered Soil: Aquents dredged from the bottom of Lake Pontchartrain for the Lakefront project.
Most Extraordinary Soil Pod: Two small pods of Commerce silty clay loam located in the eastern marshes, far from all other Commerce soils of the natural levee.

Soils and History in New Orleans

Two general rules relate the soils of New Orleans to the city's historical geography. The *closer* the soil pod is to the river (or its distributaries), the coarser the soil texture, the higher the land, the lower the organic matter and water table, the less salinity in the soil, and the better drained the soil. Ergo, the greater the likelihood the area was once a plantation, the earlier the area was subdivided and developed, and the more likely it is now home to historical neighborhoods with nineteenth-century architecture. Most of what people perceive as "classic New Orleans" stands on these soils.

The *farther* the soil pod is from the river (or its distributaries), the finer the soil texture, the lower the elevation, the higher the organic matter and water content, and the higher the salinity (particularly near the lake). Ergo, the less likely the area once hosted plantations, the more likely it was urbanized after the installation of the drainage system around 1900, the more likely it has subsided significantly, the more vulnerable it is to flooding, and the more likely it exhibits twentieth-century suburban architecture. Most modern suburban-style neighborhoods stand on these soils.

If New Orleans' physical geography were compared to a painting, the river would serve as artist, gravity as inspiration, water as brush, and soil as paint. Man has since assumed the role of artist, tinkering with the textures, depths, water content, color, and other attributes of this most fundamental environmental element. Beneath that recently altered surface lies soils laid out naturally over millennia by the Mississippi, which remain deeply influential to the history and engineering of the city. Soils played an unwritten role in the siting of

[30] Virginia R. Burkett, David B. Zilkoski, and David A. Hart, "Sea-Level Rise and Subsidence: Implications for Flooding in New Orleans, Louisiana," *Measuring and Predicting Elevation Change in the Mississippi River Deltaic System*, Louisiana Governor's Office of Coastal Activities Conference, New Orleans, Louisiana, December 8-9, 2003.

the city, its spread and development, the adjacent agricultural enterprises upon which it depended, and the natural threats it combated. Soils have also indirectly influenced the architectural character of New Orleans' neighborhoods (a function of age, in turn a function of soils), the radiating layout of its street network (based on delineations of longlot plantations, also related to soil patterns), and the location of present-day infrastructure, from interstates to skyscrapers to canals to tourism. These idiosyncratic deltaic soils—covered over and trod upon unrecognized; excavated, rearranged, and accumulated; drained by canals and penetrated by pilings—are a stealth factor in the historical geography of New Orleans.

Epilogue: Soils played a stealth factor in the Hurricane Katrina catastrophe as well. The New Orleans area was not below sea level in colonial times; rather, it traced a gradual slope from about ten feet above sea level near the river to zero to one foot at the lake. That New Orleans today is bowl-shaped and half below sea level is a result of soil subsidence induced by levee construction on the Mississippi and drainage of the backswamp. Soils also played a direct role in the failure of the levees: while initial assessments held that overtopping of the floodwalls caused the breaches, engineers later determined that heavy water pressure on a porous peat layer beneath the sheet piling allowed seepage to undermine the levees from below. Alarmingly, other small pods of peat may compromise sections of levees region-wide. The good news is that subsurface soil features such as the Pine Island Trend and the suballuvial surface may offer certain flood-control solutions: one-hundred-foot-long concrete pilings used for skyscrapers may be driven into these sturdy features to support massive new flood-control structures, such as the sort of floodgates and seawalls used in the Netherlands.

Topographic New Orleans

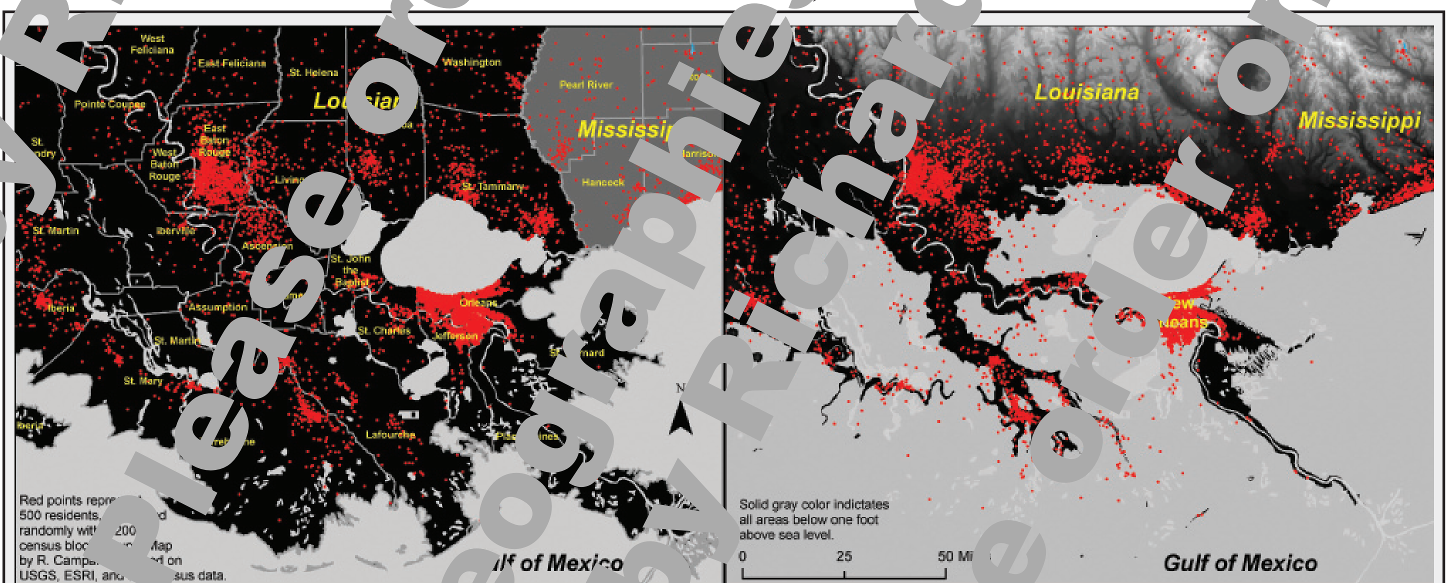
Topographic elevation is both father and son—producer and reflector, cause and effect—of the geology, pedology, hydrology, and biology of the New Orleans region. As such, it is one of the most influential physical circumstances underlying the nature and development of the Crescent City. Some may find this surprising: New Orleans, as everyone knows, is famously, comically, and *absolutely* flat. It is a city in which most people are taught that a manmade mound named Monkey Hill, built in Audubon Zoo for children to play on, is the highest point in the city. And this is, after all, a city in which that notion is not far off from the truth.[31] But such impressions of utter flatness derive from pointless comparisons to distant places, be it the bluffs of Baton Rouge or the ramparts of the Rockies. The problem is, if the subject is New Orleans, then these distant places, with all their undulation, may as well be on Mars. No one would dismiss an oasis in a desert solely because deserts lack the water of a rain forest; on the contrary, oases are among the most important and complex places in deserts. Likewise, topographic elevation is relevant in a deltaic urban environment like New Orleans because it is desperately needed and exceedingly scarce, and thus highly valuable for protection against the accumulation of water. New Orleans is *not* flat, not in an absolute sense and especially not in a relative sense. Its topographic surface straddles the level of the sea, with twenty-five to forty vertical feet separating highest and lowest areas. Not much, one may say, but enough to guide whether urban development would take place in the Age of Napoleon or in the Age of Jazz, around the Civil War or around the Cold War—and this between neighborhoods barely a mile apart. Topography in New Orleans underscores the presence of an elegant 1850s townhouse with a spiral staircase and gallery, versus a 1950s suburban ranch house with a deck and a two-car garage. Topography helps explain why most older streets follow the ancient patterns of the *arpent* land surveying system, and most recent streets form planned, orthogonal grids. Topography, in short, reflects the difference between old New Orleans—built when humans had to adapt their needs to the environment—and new New Orleans, constructed when humans gained the technology to adapt the environment to their needs. In a deltaic plain, where water threatens human settlement even as it sustains them, a few feet or even inches of topographic elevation may spell the difference between the livable and the uninhabitable, between city and wilderness, between life and death. Technology, in the form of modern drainage systems, has muted topographic elevation as a primary factor behind urbanization patterns, but not before New Orleans abided by this "first-tier rule guiding where New Orleanians built New Orleans"[32] for the first two centuries, 1718 to the early 1900s.

Measuring Elevation in Low Places

Elevation is simply the vertical distance of the land surface above an agreed-upon "zero," or vertical datum (usually, but not always, associated with the mean level of the sea). *Topography* is not quite as straightforward. Years ago, the word carried its literal meaning ("description of a place"), a concept now more commonly addressed by the word *geography* ("description of the earth"). For example, population data

[31] Monkey Hill, 27 feet above sea level, might once have been the highest terrestrial point in the city, but has since been overtaken by certain sections of the artificial levee, and by a manmade hill in the Couturie Forest Arboretum of City Park. See Richard Campanella, *Time and Place in New Orleans: Past Geographies in the Present Day* (Gretna, LA, 2002), 52-53, for further information on elevation extremes in the city.

[32] Ibid., 45.



At left is the population distribution of southeastern Louisiana displayed upon a traditional state map. At right is the same information overlaid on an elevation map, in which areas less than one foot above sea level have been "flooded." The deltaic region of Louisiana is precariously situated with respect to the Gulf of Mexico, and most of its population occupies narrow peninsula-like natural levees barely above the marshes and swamps. Coastal erosion, subsidence, and rising sea levels render these areas increasingly vulnerable to tropical storms. *Map and GIS processing by author based on USGS and 2000 Census data. Points distributed randomly within census tracts.*

published in *A Geographical Description of the United States* (1826) were entitled "Topographical Tables,"[33] a use that makes no reference to the physical terrain. Today, *topography* is usually used to describe the lay and shape of the land surface—not just elevation, but relief, curvature, slope, aspect, drainage patterns, and other effects of land shape. Loosely speaking, *elevation* is to *topography* what *temperature* is to *weather*. That a particular point is thirty-seven feet above sea level is elevation; that this point is mid-way up a north-facing, 12º slope, shedding water into a particular basin and out a certain stream, is topography. In general contexts, however, the terms are often used interchangeably.

Elevations in New Orleans have been described qualitatively since the founding of the city and quantitatively since the 1870s (earlier for certain sites), using the traditional land-surveying techniques of traverse lines, leveling, and triangulation. Field methods were supplemented with the use of stereo aerial photography and photogrammetry starting in the 1920s, enabling topographic mapping of cities and rural areas without deploying survey crews. These techniques generally measured (with increasing accuracy) the *relative* elevation of the New Orleans land surface: how high is Coliseum Square compared to Claiborne Avenue; how much lower is Lakeview than the Garden District. *Absolute* elevation, that is, the height of these features above sea level, has proven more challenging. Vertical datums used in mapping the Mississippi Valley did not even refer to sea level until the 1880s; earlier surveys were instead based on local standards such as the level of the Memphis-area flood of 1858, or the Cairo City Datum of 1871. The newly formed Mississippi River Commission (1879) tied these various vertical datums together to form the New Memphis Datum of 1880; the following year, the Commission began associating this standard with the level of the Gulf of Mexico at Biloxi, forming, by 1899, a Mean Gulf Level datum to which their surveying benchmarks were referenced.[34] Some early New Orleans elevation and bathymetric (water depth) maps from the turn-of-the-century era are based on these antiquated vertical datums, and more than a few people have confused the resultant elevation values with modern ones based on later systems, leading to erroneous results. The French Quarter riverfront was mapped as thirty-five feet high in a 1895 elevation map produced for the drainage system, but that meant thirty-five feet above the Cairo Datum, not sea level. The Cairo Datum was known at the time to be 21.[illegible]6 feet above the sea, making the riverside roughly fourteen feet above sea level, much closer to modern measurements.

To standardize measurements nationwide, the U.S. Coast and Geodetic Survey in the 1920s established a system of twenty-six tidal gauges around North American coasts to develop the National Geodetic Vertical Datum of 1929, known as NGVD1929. Many modern measurements of New Orleans elevation are based on this vertical datum, which is a plane fixed among numerous measurements of sea level, not just the level of the gulf at Biloxi.[35] NGVD1929 was superceded by the satellite-measured North American Vertical Datum of 1988, but both systems may be encountered today, and are duly cited in the corner of most standard topographic maps. Geodesists working on engineering and military applications also base elevation/height measurements on the "ellipsoid" (a mathematical model describing the slightly oblate shape of the Earth) and on the "geoid" (a construct that accounts for gravitational pull). The height or elevation of any particular locale may vary widely based on whether it is measured from the topographical, ellipsoidal, or geoidal surface.

These different standards may sound like arcane matters of concern only to mapping scientists, but they are relevant to New Orleans for a number of reasons. For one, New Orleans' elevational range is so minute that every inch counts. The land surface is also dangerously subsiding, and we really do not know by how much. Sea level, meanwhile, is rising at rates faster than it has been for the past 18,000 years (measured recently at a pace of 0.24 mm/year[36]), making New Orleans' elevation relative to the sea—and its vulnerability to hurricane-induced storm surge—that much more of an unknown. Because some benchmarks throughout the region appear to have subsided, elevations throughout southeastern Louisiana may be inches, perhaps even feet, lower than presumed. And because relationships between antiquated vertical datums and modern ones are difficult to establish, it is difficult to determine exactly how much lands have subsided in the past century, and how much more they might. For our purposes here, relative elevations are sufficient to appreciate the role of topography in the history of New Orleans, but an accurate understanding of absolute elevation—how much protection do the levees truly afford? by how much will New Orleans flood if struck by a Category 5 hurricane?—is needed to foresee New Orleans' future.

Elevation Mapping in New Orleans

Despite the dearth of lofty features, general topographic patterns of the New Orleans area were immediately apparent to the earliest inhabitants of the region. One either traversed fairly well-drained forests on higher ridges paralleling waterways, poorly drained forested wetlands (swamps), or marshes of varying degrees of salinity, and thus traveled from highest to lowest areas. Early maps depicted elevation patterns through generalized hattures or cartoonish drawings of dense canopy or murky morasses. Numerous cartographic products were published in the early to mid-nineteenth century with names such as "Topographic Map of New Orleans," but these

[33] John Melish, *A Geographical Description of the United States, with the Contiguous Countries, Including Mexico and the West Indies* (New York, 1826), 83, 137, 308.

[34] Clifford J. Mugnier, "Datums of the Lower Mississippi Valley," *Surveying and Mapping* 39 (1979): 56-58.

[35] Howard S. Rappleye, "The 1929 Adjustment of the Level Net," *The Military Engineer* 24 (November-December 1932): 576-78.

[36] As cited in Mark Schleifstein, "Tryin' to Wash Us Away," *Times-Picayune*, March 21, 2005, A1.

employed the older meaning of the word; none of these maps actually depicted contour lines or any measure of elevation.

Survey-grade elevation mapping did not arrive in New Orleans until the latter half of the nineteenth century, usually associated with the city's periodic attempts at building a drainage system, starting with City Surveyor Louis H. Pilié's drainage report to the city in 1857. The small project achieved little in draining the swamps and was interrupted by the Civil War; it was not until the 1870s that a drainage system once again became a city priority. During that decade, one of the earliest, perhaps *the* earliest, comprehensive elevation maps of the city was produced by civil engineer T.S. Hardee, under the auspices of the New Orleans Auxiliary Sanitation Association. Hardee's *Topographical and Drainage Map of New Orleans and Surroundings*, published in 1879 with one-foot contours[37] (possibly based on field data measured by the U.S. Coast Survey Department), is a modification of the better-know, hand-colored 1878 map of the same name, which does not depict elevation. The 1879 Hardee map, which depicts contours from the Mississippi to the Metairie/Gentilly Ridge, is curious. The contours are based not on sea level but on an unidentified vertical datum plane set twenty feet above a stone benchmark at Greenwood Cemetery on the Metairie Ridge. This means that the highest areas in the city—closest to the river—are labeled with the *lowest* values (as low as thirteen feet, meaning thirteen feet beneath this lofty imaginary plane) and the lowlands of the backswamp are shown with values as "high" as twenty-five feet below that plane. Thus, according to the 1879 Hardee map, the elevation range from the riverfront to the backswamp was twelve feet (thirteen to twenty-five), which, given the circumstances, is reasonable. This counterintuitive vertical datum was wisely abandoned by the next major attempt at topographic surveying, in 1893, by W.C. Kirkland, under the direction of city engineer L.W. Brown and the Engineering Committee of the Drainage Advisory Board (D.A.B). This esteemed organization was directed by the city council in February 1893 to study, design, and estimate the costs of a major system that would, once and for all, solve New Orleans' drainage problem. Topography was paramount to the group's engineering design of the drainage system: "First of all," wrote the Board in a section of its 1895 report entitled *Essential Factors for Solving the Problem*,

> it was necessary to have a topographic survey of the territory. The information available when the committee entered upon its duties, was to a large extent meagre, crude, and unreliable. It was deemed unsafe to base upon it the design of so important a project as the one under consideration. Therefore as a necessary preliminary step, a complete survey was recommended.[38]

Conducted between July 1893 and January 1895, the topographic survey entailed the traversing of forty-one "carefully measured base lines around and within"[39] the area bounded by the river, lake, Jefferson Parish line, and People's

This oblique perspective compares a satellite image to an elevation map of the New Orleans riverfront, viewed from Harvey, looking at the French Quarter (top center). *Graphic by author based on Landsat, LIDAR, and SONAR data.*

Avenue, plus some in Algiers, totaling over 150 linear miles. The board's influential 1895 report gives an idea of the thoroughness of the topographic survey:

> The entire city has been leveled over, bench marks were established at convenient points, and a record of the location and elevation [of each] registered [in reference to] the Cairo Datum. The leveling consists [of] running each leading street and obtaining the elevation of the curb, gutter, center of street and property line at intersections, and in center of block, as also the elevation of the tops of all culverts, bridges and steam and street railroad tracks at intersections.[40]

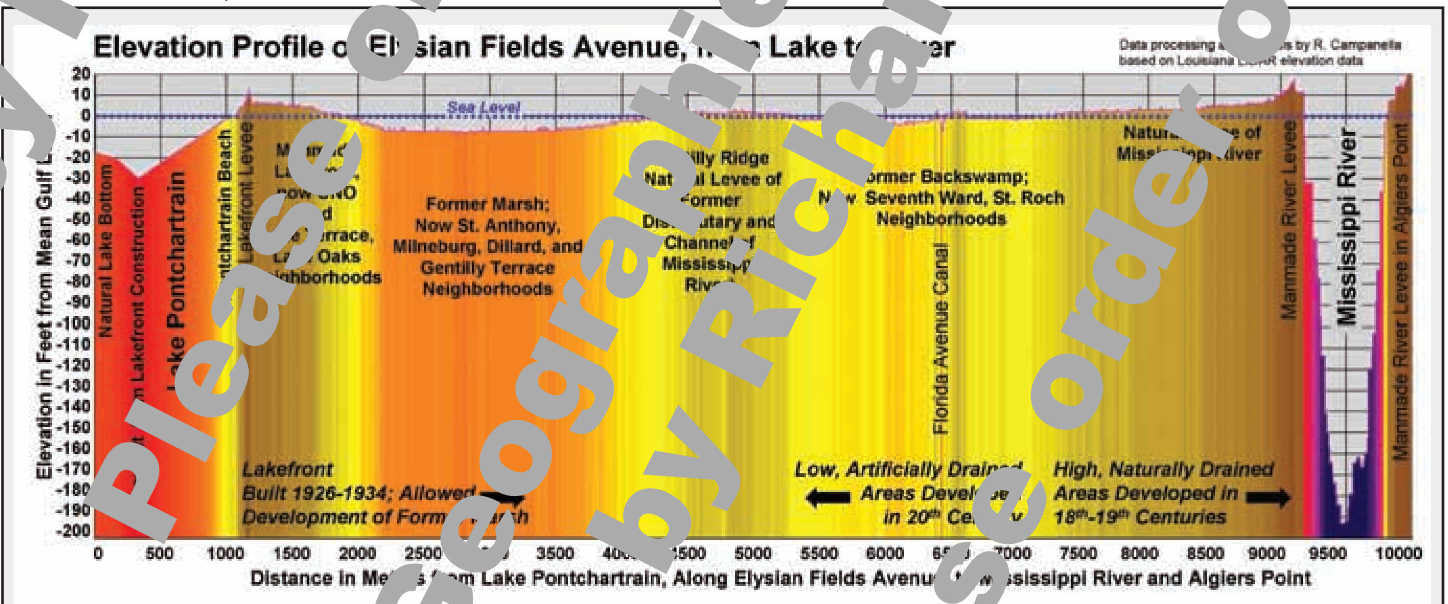
In addition, survey lines were run along canals at both surface-water level and canal bottoms, and profiles were measured for about 270 street segments through the urbanized area and rural outskirts. From these traverses and triangulations, W.C. Kirkland compiled one-foot contours and plotted them upon a detailed street network at a scale of one inch to six hundred feet, producing ten large linen maps under the title *Topographical Map of New Orleans* (1895).[41] Because the contours were based on the Cairo Datum, which was calculated at the time as 21.26 feet above sea level, the Kirkland-Brown D.A.B map shows elevations ranging from

[37] The Historic New Orleans Collection, accession number 1974.52.
[38] Drainage Advisory Board, *Report on the Drainage of the City of New Orleans* (New Orleans, 1895), 17.
[39] Ibid., 53.
[40] Ibid., 54.
[41] The Historic New Orleans Collection, accession numbers 1987.116.1 through 1987.116.12.

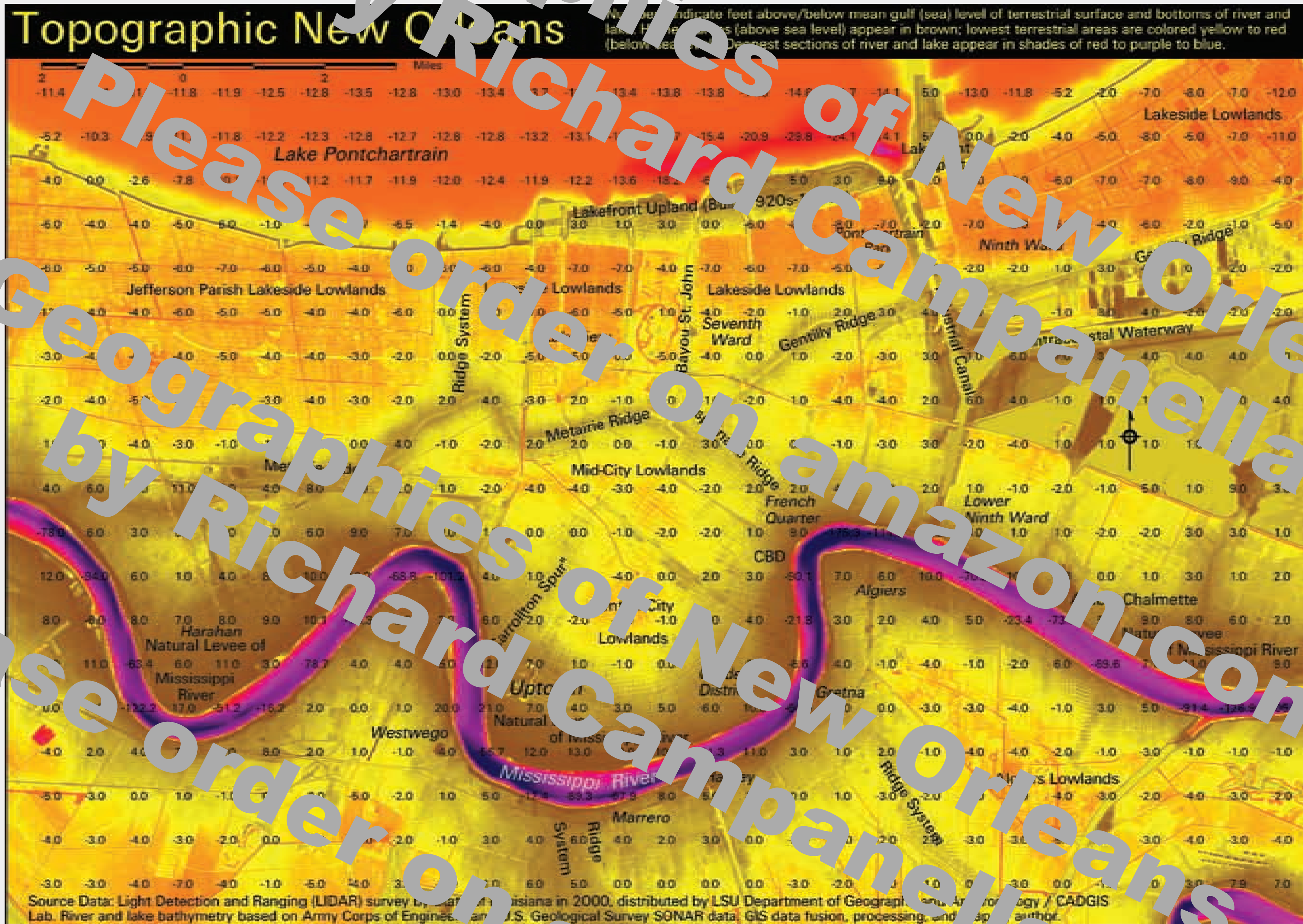
thirty-seven feet (16.74 above sea level) at the foot of Canal Street to twenty feet (-1.26 below sea level) in present-day Mid-City. The cartographic information on the linen maps was used extensively in the Drainage Advisory Board's engineering design of the complex drainage system, and was adapted as a supplement for its 1895 report to the city. This important document, representing American engineering at its best as conducted by native New Orleanians, would guide the development of one of the world's greatest urban drainage systems, still functioning today, a system which would radically augment the urban development of New Orleans. In the decades that followed, the Kirkland/Brown/D.A.B. elevation maps from 1895 were cited, copied, adapted, and modified for numerous engineering projects, by groups ranging from the Sewerage and Water Board to the Works Progress Administration, into the mid-twentieth century. The scarcity of topographic data was not peculiar to New Orleans: according to one geologist, south Louisiana in general "was one of the last major areas within the continental United States to experience detailed geological investigations," due in large part to inaccessibility. It was not until the advent of aerial photography that "accurate topographic maps of the region" were finally made.[42]

The advent of photogrammetry (the science of extracting measurements from stereo pairs of aerial photographs), increasingly demanding engineering requirements, and a changing urban surface antiquated the 1895 elevation map. Countless site-level surveys have since been conducted throughout New Orleans for various projects, but detailed, comprehensive (and very costly) surveys of the entire city are few and far between. U.S. Army Engineers conducted one such survey in 1935, and contours derived from stereo aerial photographs and plotted on standard 1:24,000 USGS quadrangles provided topographic information on the city for many years, into recent decades. In 1994, the City Planning Commission contracted Vernon F. Meyer and Associates (now 3001, Inc., a Louisiana-based mapping and surveying firm) to conduct a Global Positioning Systems (GPS) survey of the urbanized portion of the parish, based on second-order, class-1 survey standards using the North American Horizontal Datum of 1983-1986 and the National Geodetic Vertical Datum of 1929. Contours were compiled from these data points at the same interval as the 1895 maps (one foot), but because the GPS data were much denser and far more accurate than the old manually surveyed data, the 1994 contours are extremely detailed, showing practically every curb around every block. In 2000-2003, the same company, funded by the Federal Emergency Management Agency and the state, captured LIDAR (Light Detection and Ranging) data for the most flood-prone parishes of Louisiana, including Orleans, to produce topographic maps with unprecedented accuracy. This particular LIDAR sensor, mounted in an aircraft flying at 8,000 feet altitude, emits 15,000-30,000 laser pulses per second aimed at the target site. The exact time and direction of each pulse is recorded as it leaves the sensor and as it returns after reflecting off surface features. Because the speed of light is constant, the system is able to compute the distance to and from the target, and because a Global Positioning System (GPS) is integrated with the sensor, exact geodetic coordinates are associated with each pulse. From these raw data, analysts are later able to compute the precise longitude, latitude, and elevation of millions of points scattered irregularly upon the target area. Not just the earth's surface but buildings, cars, trees, vegetation, and other features are also captured, and must be removed through a post-processing algorithm to map the underlying topographic elevation. A continuous surface is then interpolated from the points,

[42] Richard P. Hohlt, "Aspects of the Subsurface Geology of South Louisiana" (Ph.D. dissertation, Rice University, 1977), 7.



Elevation profile of Elysian Fields Avenue (vertically exaggerated tenfold for visibility purposes), from Lake Pontchartrain southward to the Mississippi River and Algiers. Brown areas are the highest; red areas are below sea level. *Graphic and GIS processing by author based on FEMA LIDAR data. Lake depths are generalized.*



Elevation map of New Orleans metropolitan area, measured by airborne [illegible] for terrestrial areas and waterborne SONAR [illegible] for water depth. Posted figures indicate feet above and below mean sea level at those points. Brown areas are [illegible] red areas are below sea level. *Map and GIS processing by author based on FEMA/Army Corps/Louisiana/3001Data/LSU-CADGIS data for terrestrial areas and Army Corps/[illegible] river and lake.*

from which are extracted contours at intervals as detailed as six inches, or digital elevation models with five-meter-resolution pixels.[43] The FEMA LIDAR maps, shown in this chapter both with and without surface features, represent the most detailed and comprehensive elevation mapping ever conducted in this region, and for the city of New Orleans. Surveying crews are capable of capturing even more detailed topographic data than remote sensing devices such as aerial cameras and LIDAR, but they are usually deployed to limited areas relevant to specific engineering projects. The LIDAR data are currently being used to update the city's circa-1984 flood insurance maps, which in turn will affect the premiums of thousands of homeowners.[44]

Major Features of Topography in New Orleans

What comprises a topographic feature in the New Orleans region? If cypress trees had their say, they may bestow the status of "feature" upon low-lying swamps, eschewing other areas as uninhabitable. If the grasses of the saline marsh were to speak, they might select their boggy sea-level terrain, relegating the uplands and inland swamps to the status of wastelands. Humans in a deltaic or alluvial environment favor the well-drained uplands that support their physical passage and abodes, while dismissing the swamps and marshes of the inter-levee basins as dangerous "backswamps." Because this was the worldview of historic New Orleans—and not an unreasonable one—the "topographic features" identified in this section are those that rose above the lowlands, providing passage and living space and thus influencing the development of New Orleans.

Natural Levees of the Mississippi River — Those lands paralleling the Mississippi River rise higher than all other major natural surfaces in the deltaic region. They are to the New Orleans area what the Rocky Mountains are to North America: the major watershed, the division of drainage basins, the regional spinal column. The French described these riverside ridges as *levée* ("raised up"); the adjective *natural* distinguishes them from the man-made embankments (*artificial levees*) built upon them starting in the colonial era. Natural levees form because, as the Louisiana Geological Survey explained in 1892,

> with every flood the river…overflows its flood plain and deposits much of the sediment from its head waters. As with a slight increase in velocity the transporting power [of sediment] is vastly increased, so with a slight checking of velocity as occurs over the flood plain outside of the channel deposit takes place. The greatest decrease in velocity takes place *near* the channel, where the heaviest and coarsest sediment is deposited, and in greatest quantity. The river banks are thus built higher by each flood and a system of *natural levees* are produced.[45]

Natural levees in the New Orleans area usually stand about eight to fifteen feet above sea level, and slope backward from their crest at a declivity of about one vertical foot for every five hundred horizontal feet, forming the *backslope* of the natural levee. Beyond the backslope, which usually spans around 1.5 to two miles, lies the *backswamp*, at or below the level of the sea, where the smallest amounts of the finest clay particles are deposited. Where the river runs straight, natural levees tend to be more narrow, not as high, and less likely to break. In meandering sections, particularly in and below the Faubourg Marigny, the river has eroded into the natural levee and eliminated some streets originally platted in the early 1800s. In others, the river has deposited sediment between the levee and the water, forming a low, riverside sandbar called a *batture* ("beaten down" by the river; the opposite of *levée*). The best example of a batture is the area riverside of Tchoupitoulas in the Central Business District, built up by a combination of natural and manmade forces from the late 1700s to the 1850s. The "St. Mary Batture" has long since been incorporated into the street network and forms the Warehouse District today, an area that was in the river 280 years ago.

Artificial levees were built upon or near the crest of the natural levee starting in 1717 and expanded piecemeal until after the Civil War, when flood control became a federal responsibility, and particularly after the Great Flood of 1927, when levees and other flood control devices were augmented significantly. Topographically, artificial levees add fifteen to twenty-five feet to the crest of the natural levees; hydrologically, they constrict the river to its channel and prevent it from seasonally flooding the adjacent lands. Artificial levees are further reinforced by flood walls, concrete box levees, and revetments. This engineering success at keeping water out of New Orleans unintentionally deprived the land of new sedi-

Riverfront at Chalmette Battlefield in St. Bernard Parish: crest of natural levee at left; artificial levee with floodwall at center; willow-covered batture at right. The Mississippi flows about 150 feet beyond the batture. *Photograph by author, 2003.*

43 Robert Cunningham, David Gisclair, and John Craig, "The Louisiana Statewide LDIAR Project," www.atlas.lsu.edu.

44 Mark Schleifstein, "City Flood Maps Get Digitized Update," *Times-Picayune*, June 8, 2004, B1.

45 Louisiana Geological Survey, *Geology and Agriculture of Louisiana* (Baton Rouge, 1892), [illegible].

ments; ironically, then, the highest topographic features in the region serve to diminish the height of the entire landscape.

Despite its significance, the natural levee is almost always imperceptible to the eye, except during heavy rainstorms, when runoff in gutters flows steadily away from the river. Tchoupitoulas Street marks the crest of the natural levee through most of uptown, while North Peters, Decatur, and Chartres streets ride it from the French Quarter to the lower Ninth Ward, and Patterson Road marks the feature in Algiers. The natural levees and their backslopes are home to almost all of historic New Orleans, simply because these were the only drained lands available for urban development during the city's first two centuries. With two important exceptions—Bayou St. John and the Bayou Road/Esplanade Ridge—New Orleans' classic Creole cottages and townhouses, Greek Revival storehouses and mansions, and monumental nineteenth-century public buildings all stand upon the natural levee of the Mississippi River. Shotgun houses, too, occur on the natural levee but prevail on the rear backslope because their turn-of-the-century popularity occurred when drainage projects began to open up the lowlands. The California cottages and ranch houses of the early to mid-twentieth century are more likely found well beyond the river's natural levee, because these styles post-date the circa-1900 drainage system. Architecture is correlated to topography in New Orleans almost as strongly as vegetation is in natural ecosystems. Topography also imbued New Orleans with a distinct sense of orientation. "There is…a marked difference in the 'front lands' and the 'back lands' along the river,"[46] observed the Louisiana Geological Survey. Topographically rooted notions of the "front of town" and "back of town," still alive in the local lexicon, have deeply informed patterns of urban growth, class, race, architecture, culture, and myriad other geographies.

A satellite image of the region shows the preponderance of human existence upon these narrow river-parallel lands in the deltaic region of Louisiana. It can almost be said that, at least in terms of human geography, southeastern Louisiana *is* the natural levee of the lower Mississippi River and its distributaries, in the same manner that Egypt is a river and Australia a coast. The only exceptions are the drained backswamps of the New Orleans metropolitan area and the sparse infrastructure (ports, petroleum, transportation, etc.) actually built in southeastern Louisiana's swamps and marshes.

Metairie/Gentilly Ridge — If the natural levees of the Mississippi are the "Rocky Mountains" of New Orleans, then the Metairie/Gentilly (also called the Metairie/Sauvage) Ridge equates to the Appalachians. Though only a quarter the height and half the width of the river levees, this ridge system is significant because it formed a convenient west-to-east passageway through the swamps, uniting what is

This placid lagoon in City Park is the last remnant of Bayou Metairie, once a distributary of the Mississippi and earlier part of its main channel. The waterway formed a natural levee (Metairie and Gentilly ridge system) and other features (Bayou St. John and the Esplanade Ridge) which proved highly influential in the siting and development of New Orleans. *Photograph by author, 2005.*

today the entire metropolitan area (present-day Kenner to Chef Menteur Pass). It is also the city's most conspicuous example of an abandoned distributary, formed during the days of the St. Bernard Delta (4,300-1,000 years ago), when, for centuries, the Mississippi itself followed this path, building up present-day Metairie Road, City Park Avenue, and Gentilly Boulevard before emptying into the Gulf of Mexico due east. The Pine Island Trend, a sandy shoal pushed westward by gulf currents and now buried beneath the New Orleans land surface, helped guide the path of the river and thus the formation of this ridge. Topographic offspring of this now-abandoned main channel include obscure features like the Bonnabel Ridge (which now hosts the eponymous Metairie Boulevard), "Unknown Bayou" through New Orleans and on the West Bank, and Turtle Bayou, Bayou Pecoin, Stump Bayou, Bayou de Lassairie, and Bayou Alligator in the eastern marshes, among others.[47] Most of these features would barely influence New Orleans' future urban geography, but two, as we shall see, would play a critical role in the city's siting.

After the Mississippi attained its present channel, it continued to feed the earlier channel through an opening in the natural levee in present-day Kenner. This distributary bore a sediment load, flooded its banks, and formed its own natural levees—the same depositional processes of the Mississippi, in

46 Ibid.

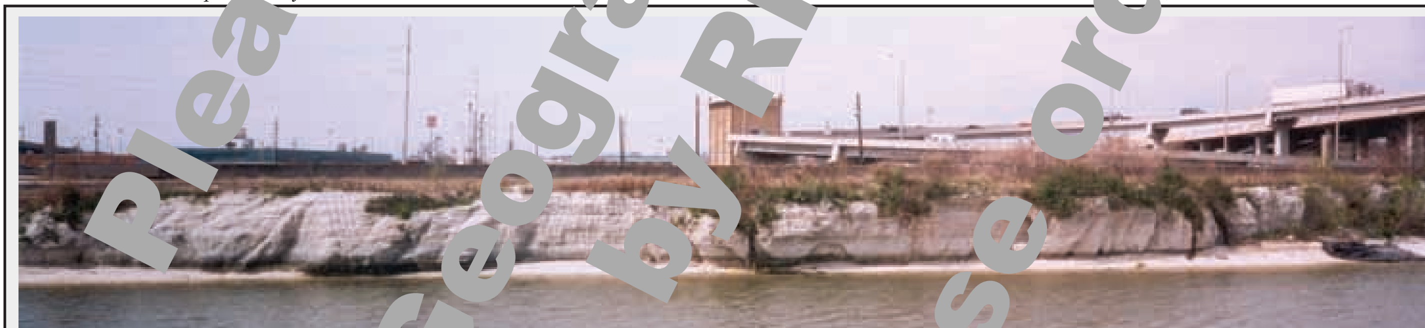
47 Roger T. Saucier, *Recent Geomorphic History of the Pontchartrain Basin*, Coastal Studies Series (Baton Rouge, 1963), 66-71.

miniature. It was still a functioning distributary during New Orleans' first century and a half, when it was known as Bayou Metairie in its western stretch, Bayou Gentilly and Bayou Sauvage to the east, and Bayou Laurel connecting the two, possibly originating as a cutoff of a meander in the distributary.[48] These bayous were closed off and sedimented by the late nineteenth century; the only surviving portions include a series of ornamental lagoons in lower City Park (remnants of Bayou Metairie) and Bayou Sauvage in eastern New Orleans. But they had their impact on the landscape: the Metairie/Gentilly Ridge today rises three to four feet above sea level and six to ten feet above the adjacent lowlands. Its natural levees are highest and widest near the origin, Kenner by the river, and progressively flatten and narrow eastward "to the vicinity of Chef Menteur Pass where they finally lose surface expression and proceed as completely buried features."[49] The ridge system attracted agriculture, transportation, and semi-rural residential living well before the adjacent lowlands were developed, and are inscribed today as curving roads (Metairie Road, City Park Avenue, Gentilly Boulevard, and Chef Menteur Highway/Highway 90) embedded in the otherwise orthogonal street network. The Metairie/Gentilly Ridge is also marked by facilities such as cemeteries, race tracks, parks, and fair grounds, located here because, when built in the 1800s, they required proximity to the population but needed too much space to be located in the city center. Once rural, they are now enveloped by the city, well situated on the upraised ridge, to the envy of homeowners living in adjacent, low-lying subdivisions. Though quite apparent in the cityscape, the actual topography of the Metairie/Gentilly Ridge is, again, all but imperceptible to the eye. Only from the Industrial Canal, which was cut through the Ninth Ward in 1918-1921, can one see the full vertical range of the Gentilly Ridge: seven to ten feet of white, sandy sediment, eroding in a manner highly reminiscent of the Badlands or features of the southwestern desert. It is a rare sight in New Orleans.

Esplanade Ridge — Between City Park and the French Quarter lies a slight ridge rising two to four feet above sea level and three to five above adjacent lowlands. Called the Esplanade Ridge for the spectacular oak-lined avenue of mansions that follows it, this topographic feature functions as a "saddle" between the Metairie/Gentilly Ridge to the north and the much-higher natural levee of the Mississippi to the south. Though minor by both absolute and relative standards, the Esplanade Ridge is of supreme historical significance, because it formed a passable trail connecting Bayou St. John, a waterway communicating with Lake Pontchartrain and thence with the Gulf of Mexico, with the Mississippi River. All other areas between Lake Pontchartrain and the Mississippi River presented impassible swamp. This meager ridge served as a critical link in the least-cost route between river and gulf used by indigenous peoples and shown by them to the early Europeans. Bienville's decision to site New Orleans at the location of the present-day French Quarter was largely based on the river/lake accessibility enabled by this ridge.

The Esplanade Ridge probably developed during the days of the aforementioned St. Bernard Delta, when the Mississippi River wended from present-day Kenner, through Metairie Road, Gentilly Boulevard, and eastward to the Gulf of Mexico. This channel seems to have meandered or forked where present-day Esplanade Avenue nears City Park, sending a distributary down the present-day avenue and into Gretna on the West Bank (which of course could not be described as such at the time). This distributary, which dried up long ago when the river attained its present-day channel, has been dubbed "Unknown Bayou" in geological literature.[50] During its active days, it formed a natural levee that, on the present-day east bank, would become today's Esplanade Ridge, and on the West Bank would form an unnamed ridge in Gretna near the Jefferson/Orleans parish line. The Esplanade Ridge was later augmented by sediments deposited by the Mississippi River in its modern channel, and to a lesser extent by the Bayou Metairie system. Viewed on a topographic map, the Esplanade Ridge appears as a "fusion" of the natural levees of these two features. The connection became a portage for Indians and early European settlers traveling from gulf to lake to river, and later the main transportation route (Bayou Road) between Bayou St. John and nascent New Orleans. So restricted was accessibility to early New Orleans by swamp and marsh that Maj. Amos Stoddard's circa-1812 description

[48] Kathleen Agnew Ward, "Ecology of Bayou St. John" (M.A. thesis, University of New Orleans, 1982), 5-8.
[49] Saucier, *Recent Geomorphic History*, 19.
[50] Ibid., 67.



This sandy bank, along the manmade Industrial Canal south of the Highway 90 bridge, is the Gentilly Ridge, deposited by the Mississippi River during the days of the St. Bernard Delta and afterwards by a distributary of the current channel. It is one of the few places in the city where natural topography is visibly evident. *Photograph by author, 2002; boat provided by CBR/Coypu Foundation.*

of the roads to the city reads practically as a topographical report:

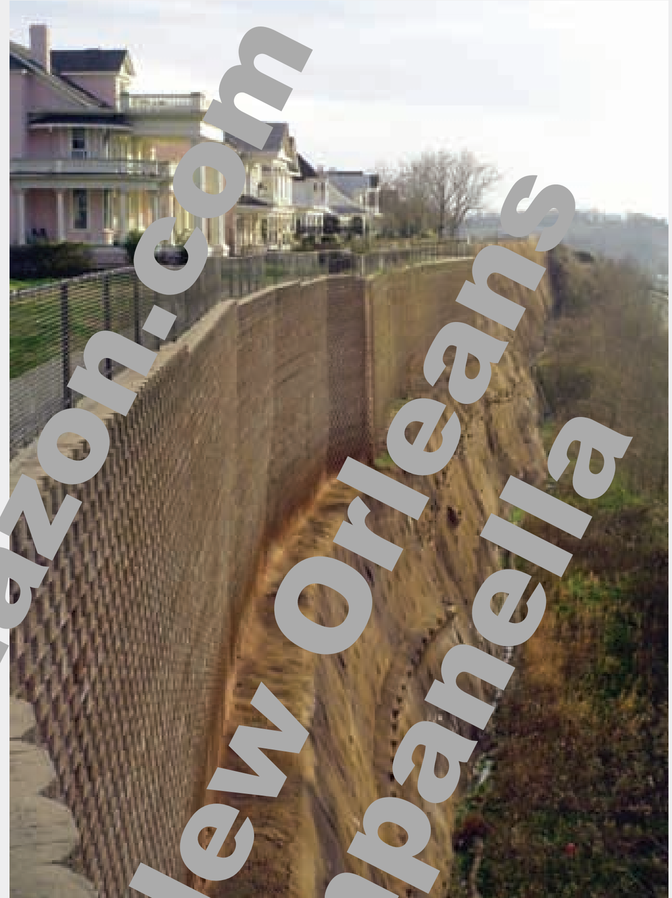
> The road [Bayou Road, following the Esplanade Ridge] leading from the back part of the city [today's French Quarter], forks two miles from the Mississippi. The one on the right [Gentilly Boulevard] runs north east on a tongue of land, about half a mile in width, generally known by the name of Chantilly [Gentilly Ridge], and terminates in the marshes and swamps [Chef Menteur Pass area] at the distance of about twenty miles. The one on the left [which becomes City Park Avenue, following the Metairie Ridge] extends about west, crosses St. John's creek [Bayou St. John] over a drawbridge, and intersects the river road [following the natural levee of the Mississippi] about fifteen miles above the city [at Kenner, where Bayou Metairie once diverted from the river channel].[51]

As would a road through the wilderness, Bayou Road curved gently through the swamps to exploit the Esplanade Ridge, and to this day, the slight bend in Bayou Road remains in the streetscape. Beneath that graceful arc is one of New Orleans' most significant topographic serendipities, without which New Orleans would be vastly different today, for Bienville presumably would have located the city elsewhere.

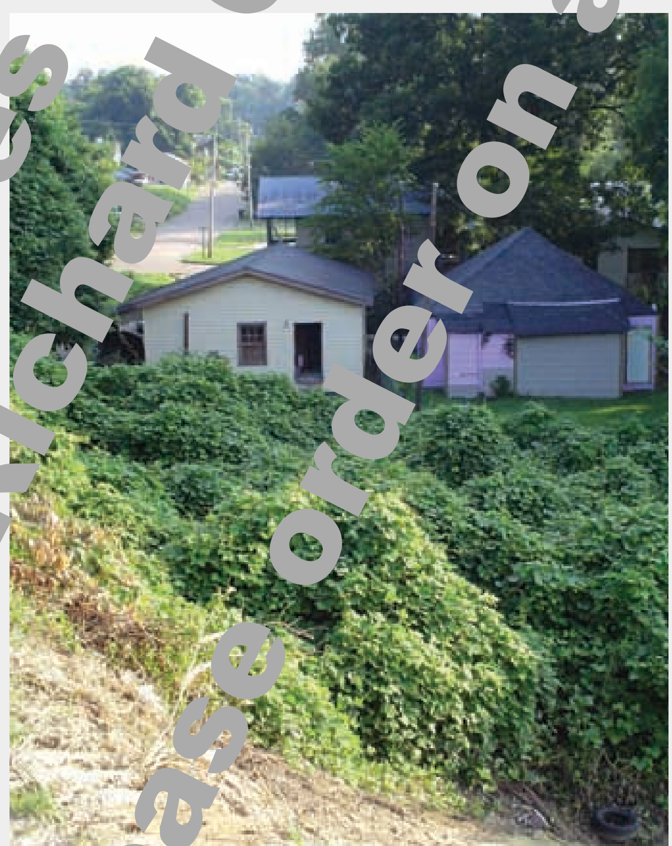
Bayou St. John — This minor waterway is not a topographic feature in the sense of an upraised terrestrial ridge. But Bayou St. John spawned from such a feature, and played so an important a role in the early history of New Orleans that it warrants inclusion here.

Bayou St. John is a sibling of the Esplanade Ridge, offspring of the same former channel of the Mississippi River that once flowed along the Metairie/Gentilly Ridge. As described earlier, it is theorized that this channel formed a sharp meander near the present-day entrance to City Park, before continuing eastward. At one point in the meander, a distributary was deflected southward to form the Esplanade Ridge. At another, a smaller distributary broke off northward, becoming Bayou St. John. Alternately, or perhaps additionally, after the Mississippi abandoned this channel and the much lesser Bayou Metairie and Bayou Gentilly continued to trickle through it, a crevasse or perhaps a fault in this waterway continued to send water out Bayou St. John to the lake.[52] Because of its short distance, its isolation from the new channel of the Mississippi, its minute sediment load, and the tidal effects of the lake, Bayou St. John never formed natural levees. Rather, it was a narrow, clogged, slack-water inlet through which tidally influenced brackish lake water intruded into the marshes. This was the portage most likely shown to Iberville on March 9, 1699, who recorded,

> the Indian who accompanied me revealed a terminus of the portage [Bayou St. John] from the southern shore of the bay [Lake Pontchartrain], where the Indian boats land in order to descend to this [Mississippi] river. They drag their canoes along a path [Bayou Road], where we found the baggage of people who are either leaving or returning by way of this portage. This Indian, our guide, took a parcel there. He remarked



Mansions atop the bluffs of Natchez; shacks in the bottomlands of Vicksburg. In these Mississippi cities and elsewhere, higher elevations in urban areas are often associated with wealth, while poorly drained bottomlands are usually associated with poverty. The relationship between elevation and socio-economics in historic New Orleans, however, is more complicated. *Photographs by author, 2003-2004.*



[51] Major Amos Stoddard, *Sketches, Historical and Descriptive, of Louisiana* (Philadelphia, PA, 1812), 162.
[52] Ward, "Ecology of Bayou St. John," 3-9.

that the distance between one end of the trail and the other is indeed inconsiderable.[53]

Bayou St. John's era of historical significance lasted from that moment in 1699 to the 1830s, when the Pontchartrain Railroad and New Basin Canal superceded the bayou (and the adjoining Carondelet Canal) as the most efficient route to the lake. The bayou we see today is a sanitized, mostly ornamental descendent of the original waterway, having been dredged, drained, straightened, dammed, paved, pumped, and altered in every way imaginable. But the general channel and path remain.

Carrollton Spur — A slight upland underlies the uptown neighborhood of Carrollton, running along South Carrollton Avenue from the Mississippi River to about Earhart Boulevard. This is the natural levee of the Mississippi, but here it rises slightly higher and extends farther inland than elsewhere uptown. The formation of this "Carrollton Spur" can probably be traced to crevasses that opened periodically along present-day Leake Avenue, most notably in 1816 and in 1832, when a 150-foot break in the levee near present-day Leonidas Street flooded New Orleans from the rear and coated Carrollton with valuable fresh sediments.[54] This area is located on the cut-bank side of a sharp river meander, where the trajectory and the velocity of the current make it more likely to puncture the natural levee and flood the land. Carrollton was thus subjected to slightly more sediment deposition and rose to be higher than adjacent natural levees, by roughly one to two feet.

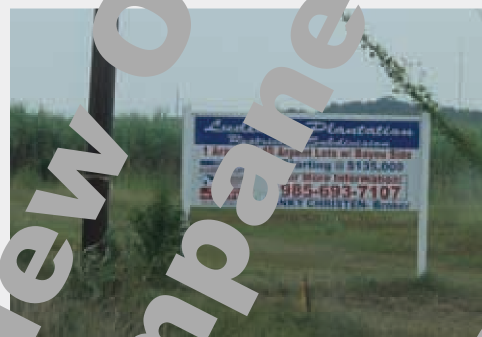
There is one interesting "non-consequence," and one important historical consequence, of the Carrollton Spur. Because this feature falls short of adjoining the Metairie/Gentilly Ridge, as the Esplanade Ridge does on the opposite side of the crescent, Indians and early explorers did not have direct foot access to the Carrollton area from Bayou St. John. Carrollton was therefore isolated from the main corridor of development activity during New Orleans' first century. Had the Carrollton Spur adjoined the Metairie/Gentilly Ridge, early inhabitants would have had two routes to the river, shaped like the legs of a wishbone (with Bayou St. John as the trunk), perhaps fostering the development of a secondary settlement at Carrollton in the eighteenth century. But a 1,000-foot gap between these two ridges, located around the present-day Carrollton I-10 interchange, prevented this. It was not until 1833 that this area, previously operating as the Macarty sugar plantation, was finally developed as the city of Carrollton. The town's main avenue and subdivided streets exploited the Carrollton Spur by extending deep into the middle of the crescent, considerably beyond other subdivided former plantations. Carrollton, annexed into New Orleans in 1874, today exhibits architectural styles, trees, and an overall look-and-feel that are a generation older than other areas equally distanced from the river. This cityscape is a consequence of the area's topography.

Lakefront — Man has altered the elevation of almost every terrestrial acre of Orleans Parish, either deliberately by constructing levees, filling swamps, and excavating canals, or inadvertently by causing subsidence and erosion. But only one extensive area was built up from literal sea level to become one of the highest places in town, dramatically altering the lay and shape of the New Orleans landscape. This was the Lakefront project, a highly successful flood-protection and land-reclamation effort envisioned as early as 1873 and finally executed sixty years later.

The Lake Pontchartrain shore known to most nineteenth-century New Orleanians comprised only the resorts of Milneburg, Spanish Fort, and West End, which formed the lakeside termini of three important city-to-lake corridors: the Pontchartrain Railroad on Elysian Fields Avenue, Bayou St. John, and the New Basin Canal, respectively. The rest of the lakeshore and its adjoining marshes were, from the perspective of most city dwellers, a marshy wasteland useful only for fishing and crabbing. But once the installation of the municipal drainage system (1893-1915) dried the lakeside marshes, New Orleans expanded off its 180-year confinement to the natural levees and cast its eyes to the once-useless lakefront marshes. With urban development rapidly expanding toward the lake starting in the 1910s, the prospect of a hurricane-induced lake surge loomed as a serious threat to the growing city. Levees were built along the shore in the early 1900s, but the high quantity of water and organic matter in the fine clay sediments deteriorated them. Then, in the 1920s, public support mounted for a plan envisioned a half-century earlier by city surveyor W.H. Bell, *Plan of Property Improvements for the Lake Shore Front of the City of New Orleans* (1873). Bell's latter-day protégés proposed building a levee half-a-mile into the lake and pumping sediments from lake bottom into the corralled area, creating a new upland that would protect the New Orleans basin from storm surges while offering lakefront recreational and residential opportunities. The ambitious engineering project was started in 1926 and finished, complete with an airport, in 1934. Over the following decades, Lakefront New Orleans was developed with recreational facilities, waterfront vistas, suburban neighborhoods, lagoons, and everything else that New Orleanians only dreamed of. In an area that was once water, the Lakefront now spans 2,000 acres and rises four to six feet above lake level and over ten feet above adjacent lowlands, higher than the Metairie/Gentilly Ridge and almost half as high as the Mississippi River's natural levees. When viewed from above, the change is even more striking: whereas earlier the Lake Pontchartrain shore formed a smooth arc around the southern edge of the lake, now the Lakefront and its airport jut abruptly into the lake,

[53] Carl A. Brasseaux, trans. and ed., *A Comparative View of French Louisiana, 1699 and 1762: The Journals of Pierre Le Moyne d'Iberville and Jean-Jacques-Blaise d'Abbadie*, 2nd ed. (Lafayette, LA, 1981), 44. It is possible that Iberville was describing a portage located farther upriver, such as Bayou Tepagnier.

[54] Williams H. William, "The History of Carrollton," *The Louisiana Historical Quarterly* 22 (January 1939): 189.



The French tradition of surveying riverine lands into “longlot” plantations, measured by the old French unit arpent (192 feet), transformed the natural levees of the deltaic plain into agricultural landscapes. Arpent-system plantations may be seen today as elongated parcels extending off the Mississippi River and its distributaries from the natural levee to the backswamp, a distance of usually forty or eighty arpents (1.5 to three miles, shown on the above River Road satellite image as red and yellow lines). Old arpent-system lots in present-day uptown New Orleans, formerly sugar plantations, were urbanized throughout the 1800s, leaving their imprint in the radiating street network of the modern city. The *arpent* has long since been replaced by English acres and feet, but the term is still occasionally referenced in the landscape. This real estate sign near Lockport, for example, demonstrates continued popular usage of *arpent*. “Eighty Arpent Road” in Jefferson Parish marks the rear edge of old West Bank plantations. *Photograph of real estate sign by Mark F[illegible] and Kevin A. Caillouet, 2004; map and street sign photograph by author, 2003.*

like the knuckles and thumb of a partially clenched fist. The project was a success—“one of the very few places where twentieth century city planning has truly improved a large area of an American city”[55]—and remains so today, by almost everyone's measure.

A Dynamic Topography: Soil Subsidence and Coastal Erosion

River-deposited sediments occupy a volume bloated by water content. As the water drains away, the soil volume consolidates; particles settle under their own weight and fill in air pockets; and organic matter disintegrates, opening up more space for compaction. Crustal sinking and tectonic activity also sometimes occur. The result: subsidence, “the lowering of the elevation of a land area in relation to sea level.”[56] A natural process in the deltaic plain, subsidence is normally counterbalanced by incoming deposits of sediment-laden floodwaters, made at roughly the same pace. Deltaic regions maintain topographical equilibrium so long as the sustaining river does not meander away, or the level of the sea does not change.

Or so long as man does not constrict the river with artificial levees, which prevent inundation of cities and farms but simultaneously restrict new sedimentary deposits to the deltaic bank account. That is what has happened in southeastern Louisiana. New Orleans' topographic elevation is presently diminishing, in absolute terms and particularly in relation to sea level, which, in a conspiracy of factors partially of man's own doing, happens to be rising at increasing rates. Subsidence is not an arcane scientific preoccupation in New Orleans; it is a topic of everyday conversation, inspiration for the sort of doomsday humor that binds the residents of New Orleans with those of other colossal urban-engineering challenges, such as Mexico City and Venice. It is also nothing new: “Rumor says that New Orleans is slowly sinking,” reported the *Harper's Weekly* in 1871. “In one locality a batture…has sunk seven feet below the ordinary level.”[57] Subsidence became a household word during the oil-boom years of the 1970s, when rapid urbanization of the recently drained marshes of Jefferson Parish landed the issue on the front page of local newspapers. That five suburban houses on Jefferson Parish's high-peat soils literally exploded because of subsidence-related breaks in gas lines only added to the city-wide preoccupation.[58] A survey of headlines from 1972 to 1979, culled from a bibliography on soil subsidence by Christine Moe, sheds light on how the public learns of an unintended

[55] Peirce F. Lewis, *New Orleans: The Making of an Urban Landscape* (Cambridge, MA, 1976), 66.
[56] Roger T. Saucier, *Geomorphology and Quaternary Geologic History of the Lower Mississippi Valley*, 2 vols. (Vicksburg, MS, 1994), 1:53.
[57] “Home and Foreign Gossip,” *Harper's Weekly*, October 14, 1871, p. 963, col. 2.
[58] J.O. Snowden, [illegible] Ward, and J.R.J. Studlick, *Geology of Greater New Orleans: Its Relationship to Land Subsidence and Flooding* (New Orleans, 1980), 17. The five houses, which exploded between 1972 and 1976, were located within one mile of the Veterans Boulevard/David Drive intersection.

environmental consequence, struggles with it, and eventually tries to resolve it.

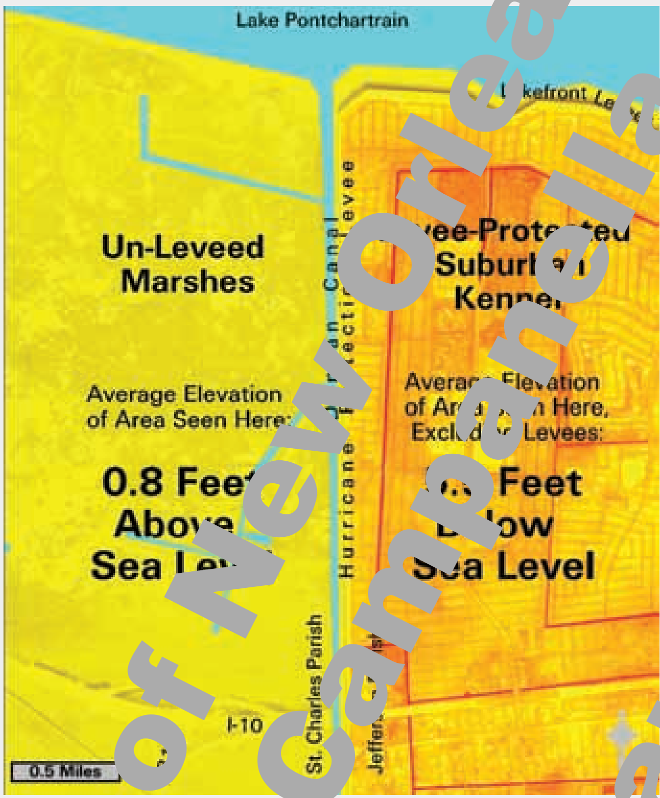
Headline	Date	Author, Newspaper
"Marshlands in Trouble – Homeowners Are Too"	11/1/7[illegible]	*Times-Picayune*
"Wetlands in Trouble; Drained Marshland Poses Hazards"	5/28/74	*Times-Picayune*
"Rats, Nutria, Snakes, and Mosquitoes—Not to Mention Sinking Backyards"	7/28/74	*Times-Picayune*
"Gas Explosion Destroys House"	1/20/77	*Times-Picayune*
"How Can You Cope With Sinking Soil?"	2/2/77	*Jefferson Parish Times*
"Soil Sinkage News Not Good for Kenner"	2/[illegible]/77	*States-Item*
"Soil Survey Needed"	2/[illegible]/77	*Times-Picayune*
"Administration Reacts to Explosions"	2/[illegible]6/77	*West Bank Guide*
"Soil Testing Starts in East Jeff"	3/26/77	*Jefferson Parish Times*
"Warning: Hazardous Soils"	3/28/77	*Times-Picayune*
"East Bank Soil Sinkage 'Severe'"	3/30/77	*Times-Picayune*
"Gas Firm Halts Service Expansion, Kenner May Fight	4/19/77	*States-Item*
"Steps Urged to Prevent Jeff Gas Blasts"	6/9/77	*States-Item*
"Louisiana Gas Sues Jeff, Says Parish P[illegible] Fault for House [illegible]s"	7/6/77	*Times-Picayune*
"Soil Survey Finds Muck in Metairie"	7/15/77	*States-Item*
"Flexible Gas Lines Urged for Jefferson"	9/1[illegible]	*States-Item*
"Seeking Solutions to [illegible]'s Soil Subsidence"	[illegible]/77	*States-Item*
"Soil Map of Jeff Tells 'Hole' Story"	9/[illegible]9/77	*States-Item*
"E. Jeff Soil Not Best for Building"	10/3/77	*Times-Picayune*
"Subsidence Panel Established"	10/6/77	*States-Item*
"What Are Ways to Cope with Subsidence?"	10/6/77	*States-Item*
"Study Shows Jeff Land Unsuitable for Urban [illegible]"	10/6/77	*States-Item*
"Land Developers Asked to Provide Soil Subsidence, Foundation Data"	10/19/77	*West Bank Guide*
"Development Sl[illegible] Recommended in Jeff"	10/25/77	*East Bank Guide*
"Resolution Offered to Curtail Soil Subsidence"	10/26/77	*East Bank Guide*
"Builders Seek Help in Kenner"	10/26/[illegible]	*Times-Picayune*
"Parish Seeks New Soil Study"	11/2/77	*East Bank Guide*
"Soil Reports by Developers Urged in Jeff"	[illegible]1/9/[illegible]	*States-Item*
"West Bank Couple to File 'Sinkage' Suit"	11/9/77	*States-Item*
"Smile: Your House Is [illegible]"	11/10/77	*States-Item*
"Soil Study Requirements Are Proposed"	11/16/77	*East Bank Guide*
"Halt Marsh Development for Soil Study, Team Urges"	12/10/77	*States-Item*
"Builders Soon May Need Soil Test Prior to Permit"	12/21/77	*East Bank Guide*
"Some Subsidence Blamed on Builders"	1978	*Times-Picayune*
"Jeff Requires Report for New Subdivisions"	2/1[illegible]/78	*Times-Picayune*
"Warning: House May Sink"	2/1[illegible]/78	*States-Item*
"Couple Wins, Loses in Sinking-Home Suit"	2/1[illegible]/78	*Times-Picayune*
"Homes North of Jeff Line May Pay for Gas Hoses"	8/16/78	*States-Item*
"Ordinance Would Require Jeff Soil Sinkage Data	10/25/7[illegible]	*Times-Picayune*
"Jeff Soil Sinkage: Seller Can Be Mum"	11/[illegible]/78	*States-Item*
"West Bank Is on Shaky Ground"	12/1[illegible]/78	*Times-Picayune*
"Soil Sinkage Plagues 84% of West Jeff"	12/[illegible]/78	*States-Item*
"They're Losing Ground"	12/16/78	*States-Item*
"Sinkage Help Urged for W. Jeff"	12/21/78	*States-Item*
"Jeff Council Declares New Gas Connectors Necessary"	1978?	*East Bank Guide*
"Building Code Is Target of New Jeff Panel"	1/25/79	*States-Item*
"Jeff to Consider Requiring Pilings Over Sinking Soil"	3/7/79	*Times-Picayune*
"[illegible] Law Requires Pilings"	3/8/79	*Times-Picayune*

New Orleans is located in the heart of the world's largest subsiding coastal region, stretching from Mexico to New York, far larger than the world's other forty-two coastal areas experiencing significant subsidence.[59] The city itself is one of [illegible]teen subsidence zones in the nation, and while certain Western valleys and cities (which have over-tapped their groundwater)[60] are subsiding faster, New Orleans' situation is arguably the most dire because of the city's proximity to an eroding coast and a rising sea.

Although its affects—broken cornerstones, buckled streets, cracked and leaning buildings—are visible to the eye, subsidence is difficult to measure precisely over an extensive area. Researchers have quantified these subtle changes through the use of historical maps, structural observations, tidal gauges, geodetic surveys of benchmarks, gravity meters, radiocarbon dating of buried organic matter extracted

[59] Eric C.F. Bird, *Submerging Coasts: The Effects of a Rising Sea Level on Coastal Environments* (Chichester, New York, Brisbane, Toronto, and Singapore, 1993), 4-5.

[60] A. Ivan Johnson, "Land Subsidence Due to Fluid Withdrawal in the United States—An Overview," in *Land Subsidence: Case Studies and Current Research*, ed. James W. Bo[illegible] (Belmont, CA, 1998), 52.



LIDAR-based elevation data captured in 2000 revealed how much the levee-protected soils of metro New Orleans had subsided below adjacent un-leveed marshes (themselves eroding). This portion of Kenner (right) lies about five feet below the marshes to the west and the lake to the north, protected only by the very levees that caused the subsidence. *Map by author based on LIDAR data.*

through borings and—today—through the sub-centimeter accuracy of integrated networks of Global Positioning Systems stations. Still, results often vary widely among points within a single study, and average rates vary almost as much between studies. Literature on subsidence rates is replete with phrases like "as high as," "up to," or "in some areas," which reflect high variability and the failure of a single, "official" mean rate. Such is the case in New Orleans, where factors such as "geology, soils, hydrology, well locations and water withdrawal…levee locations, drainage pumping station sites…the history of drainage and settlement, application of fill and overburden, the bulk and density of buildings, and land use"—drive the rate of subsidence at any given spot.[61] The influence of even basic factors, such as elevation, is not clear. The conventional wisdom holds that subsidence is more severe in low-lying inter-levee basins than in higher areas of the city based on natural levees, because the lowlands' higher water and organic content, once drained, allows for greater settlement of their finer-grained particles. But actual field data often refute this generality. For example, benchmarks measured between 1951 and 1995 by the National Geodetic Survey show that, for the most part, those on higher ground sunk by more than five millimeters per year, and many of those on lower ground subsided by less than that amount.[62] Indeed, in some cases "natural levees and barrier sands, due to their higher bulk density, may actually subside faster than surrounding clay and organic sediment."[63] Nevertheless, most researchers agree that the low-lying peat deposits of former saline marshes, such as the lakeside and eastern New Orleans neighborhoods, subside the fastest when drained and developed for the first time.

A Survey of Subsidence Measurements in the New Orleans Region		
Subsidence Measurement	**Conditions**	**Source**[1]
Average of 5 mm per year	Leveed area of metropolitan New Orleans measured five times between 1951 and 1995	National Geodetic Survey, as cited by Burkett, Zilkoski, and Hart (2003)
As much as 1 cm per year	North central Gulf Coast region	As cited by Burkett, Zilkoski, and Hart (2003)
Average of 20.7 cm/ century, with a range from 5.5 to 123.7 cm/century	Based on radiocarbon analysis of [illegible] borings taken throughout Louisiana deltaic plain	Henry (1996)[2]
Average of 9.2 mm per year	Averages of hundreds of test points, mostly on natural levees, measured between 198[illegible] and 1991.	National Geodetic Survey, as cited by Hart and Zilkoski (1994)
Average of 0.52 feet/century	Central Louisiana coastal plain	Roberts (1985)
Range from 0.40-[illegible].2 feet/century	Barataria Basin	Kosters (1983)
Average 1.05 feet/ century	Generalized rate for deltaic plain	Penland and Boyd (1983)
As much as 6-7 feet over several decades	Maximum rate in parts of New Orleans metropolitan area	Kolb and Saucier (1982) as cited in Saucier, *Geomorphology and Quaternary Geologic History*, 1:54.
Average of 0.36 feet/ century	Generalized rate for deltaic plain	Gagliano and Van Beek (1975)
Average of 0.39 feet per century for past 4400 years	Generalized rate for Pontchartrain Basin, based on radiocarbon dating of peat deposits	Saucier, *Recent Geomorphic History* (1963), 13.
Average of 0.78 feet/ century	Southeastern Louisiana deltaic plain, accounting for sea level rise of 0.[illegible]2 feet/century	Kolb and Van Lopik (1958), as cited in Saucier, *Geomorphology and Quaternary Geologic History*, 1:53.

[61] David Hart and David Zilkoski, "Mapping a Moving Target: The Use of GIS to Support Development of a Subsidence Model in the New Orleans Region," *Urban and Regional Information Association (URISA) Proceedings, 1994*, http://www.odyssey.ursus.maine.edu/gisweb/spatdb/urise/ur94049.html.

[62] National Geodetic Survey, as cited by Virginia R. Burkett, David B. Zilkoski, and David A. Hart, "Sea-Level Rise and Subsidence: Implications for Flooding in New Orleans, Louisiana," *Measuring and Predicting Elevation Change in the Mississippi River Deltaic System*, Louisiana Governor's Office of Coastal Activities Conference, New Orleans, Louisiana, December 8-9, 2003.

[63] Snowden, Ward, and Studlick, *Geology of Greater New Orleans*, 14.

As much as 3-6 feet over 40 years	Maximum observed subsidence in certain areas, starting after installation of drainage system (1897), to 1937	Work Progress Administration (1937), 3.

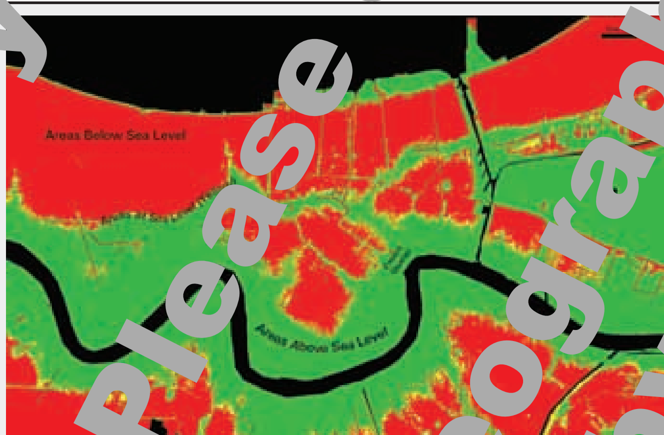
[1] According to Roberts, Kosters, Penland and Boyd and Gagliano and Van Beek, as cited in Charles Sanders Henry, III, "Long-Term Relative Subsidence Rates: Mississippi River Deltaic Plain" (M.A. thesis, University of New Orleans, 1996), 3.
[2] Ibid., viii-ix.

"The query is—What can be done?" asked the *Harper's Weekly* about subsidence in New Orleans in 1871.[64] To date, no satisfactory "master formula" has been developed to characterize fully the phenomenon of subsidence, a challenge like "trying to map a bowl of vibrating jello," according to two mapping scientists so quoted.[65] The mandated use of pilings under new house construction in certain areas, the recommended use of flexible utility connections, and artificial fill by the truckload counter the worse effects of subsidence in the metropolitan area, but the problem itself may be unsolvable. Homeowners respond by shoring up their raised houses with jacks and pilings, or, more desperately, watering the underlying soil with a garden hose during dry spells. Greater New Orleans is home to more shoring specialists per capita than any other major American city; one, Abry Brothers, has been in business since the 1840s.

Subsidence is relevant to a discussion on New Orleans topography for the obvious reason that it alters the elevation of the land surface. The recent topographic surveys discussed in this chapter will probably be as obsolete in the twenty-second century as the Hardee and Kimball-Brown-D.A.B maps of the nineteenth century are today. "Considering the rate of subsidence and…sea level rise," wrote the authors of a recent scientific paper, "the areas of New Orleans and vicinity that are presently 1.5 to three meters below mean sea level will likely be 2.5 to 4.0 meters or more below mean sea level by 2100."[66] The very fact that forty-nine percent of greater New Orleans today is below sea level[67] can be attributed to anthropogenic subsidence: "this is not a natural condition," wrote geologist Roger T. Saucier, in reference to extensive areas falling well below sea level in a deltaic plain.[68] The sinking land surface threatens New Orleans' infrastructure and handicaps the city's ability to survive the lake and gulf surges of powerful hurricanes. The threat was real enough in 2004 to convince the East Jefferson Levee District, "in an overabundance of caution," to erect three-foot-high, interlocking sand-filled baskets along 6,800 feet of sinking lakefront levee between Lake Villa Avenue and Causeway Boulevard in Metairie. "It's better to be safe than sorry," reflected Levee Board president Patrick Bossetta.[69] A few months later, Hurricane Ivan, which narrowly spared the city but devastated the Alabama and Florida Gulf Coast, made this precaution seem like a particularly wise move.

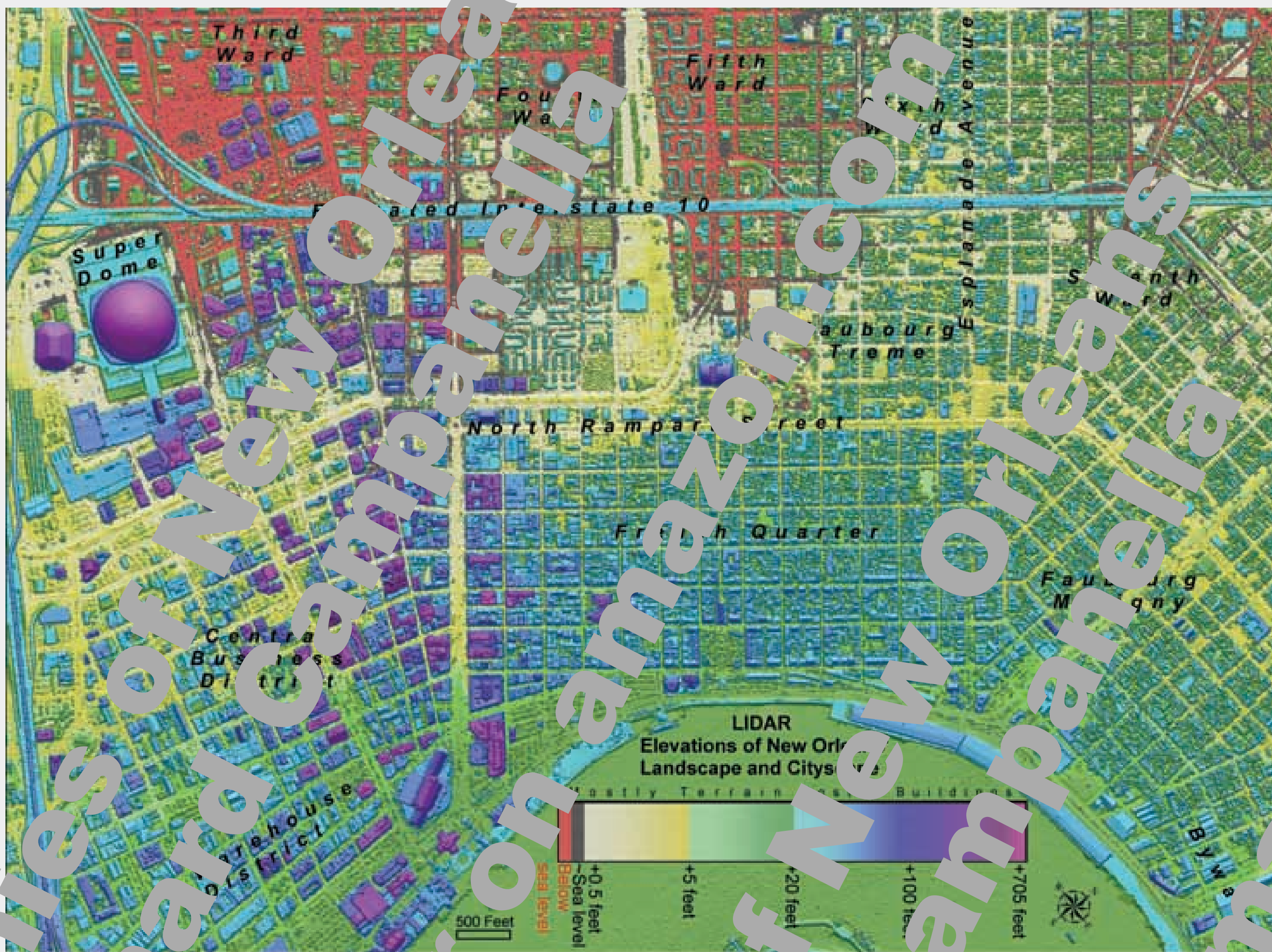
Subsidence is also pertinent to this discussion because it is the ironic consequence of topographic engineering, and not the only one. The sediment-starved deltaic region is now not only subsiding vertically but eroding horizontally. Southern Louisiana has lost over 1,500 square miles of coastal lands since the 1930s and currently loses an additional twenty-five to thirty-five square miles per year, or an acre every twenty-four minutes. Swamps that were once verdant are now half-killed by intruding salt water. While most researchers generally agree that flood-control levees on the river are the root cause of this gradual catastrophe, other factors exacerbate the problem. Canals built for navigation, oil and gas exploration, and trapping have expanded erosion-prone land/water interfaces; protective grasses are destroyed by invasive nutria and by high salinity levels and droughts; and compacting soils lower the relative land height in relation to rising gulf waters. New Orleans proper suffers its share of this loss, in the marshes of eastern Orleans Parish. Coastal erosion in neighboring parishes is an even greater threat to the city, not to mention to those parishes themselves, because it brings the potentially tempestuous Gulf of Mexico ever closer to the low-lying metropolis. Every 2.7 miles of wetlands that disappear allow an additional foot of gulf water to surge inland in front of an oncoming hurricane; some put the ratio at one mile to one foot. "The city will lose the wetland buffer that now protects it from many effects of flooding. As a result, severe floods will occur more frequently, and the strain on the area's already overtaxed drainage system will increase."[70] The diminishing verticality of the land has added a new eleva-

[64] *Harper's Weekly*, October 14, 1871, p. 9_6, col. 2.
[65] Hart and Zilkoski, "Mapping a Moving Target."



Conventional wisdom has it that New Orleans is "below sea level." In fact, the metropolis straddles the mean level of the sea: 44 percent of the metropolitan area is above it (green), 7 percent is at sea level (yellow), and 49 percent is below it (red). Prior to European settlement, the area was entirely at or above sea level. *Map and analysis by author based on LIDAR data.*

[66] Burkett, Zilkoski, and Hart, "Sea-Level Rise and Subsidence," abstract.
[67] Seven percent of the terrestrial surface of greater New Orleans is at sea level and the remaining 44 percent is above it. Percentages computed from LIDAR digital elevation models covering from 90° 15' West, 29° 53' North to 89° 56' West, 30° 03' North (roughly from Westwego to Little Woods).
[68] Saucier, *Recent Geomorphic History*, 5 (emphasis added).
[69] Sheila Grissett, "Baskets of Sand Temporarily Build Up Jeff Levee," *Times-Picayune*, July 8, 2004, East Jefferson Metro Section, B1.
[70] As quoted in Mark Schleifstein, "Louisiana Coastline in Dire Straits," *Times-Picayune*, February 2_, 1999, A1.



This LIDAR elevation map of downtown New Orleans, unlike others in this chapter, depicts the height of structures, trees, and other features in addition to surface elevation. *GIS processing and map by author based on "raw" LIDAR data points from FEMA.*

tion-based dimension to hurricane preparedness: when those with means flee the city as a hurricane approaches ("horizontal evacuation"), public officials devote their resources to the "vertical evacuation" of those without means—that is, moving the infirm and the poor into high buildings. Hurricane season brings annual awareness to over one million people of the topographic precariousness of their home, and of its eroding coastal buffer. If current trends continue, New Orleans may occupy the tip of a narrow peninsula protruding into the Gulf of Mexico by the early twenty-second century, possibly sooner. With this nightmare scenario in mind, and with the disheartening prospect of a world without southern Louisiana, massive engineering attempts to slow and reverse the pace of coastal land loss have been proposed and enacted. Most call upon the Mississippi River, creator of this land and topic of the next chapter, to restore the topography of the deltaic region. As topography has played a profoundly consequential role in New Orleans' first three centuries, it will make or break the city in the next century.

Epilogue: The once-arcane topic of New Orleans topography received worldwide media publicity, complete with detailed maps and three-dimensional diagrams, in the aftermath of Hurricane Katrina. As Lake Pontchartrain's waters inundated the metropolis via multiple levee breaches, the few feet of elevation that differentiated the landscape imperceptibly to the naked eye dramatically spelled the difference between survival or destruction of entire neighborhoods. Those areas above sea level, developed in the 1700s and 1800s and home to sturdy historical housing, mostly evaded deep and persistent flooding. Those areas below sea level, developed largely in the 1900s with slab-based housing, suffered inundation to a degree precisely commensurate to their elevation, or lack thereof. Satellite images captured after the deluge showed only the natural ridges of the Mississippi, Metairie, Gentilly, Esplanade, and Carrollton in their normal dryness, amid a sea of dark floodwaters.

Topography served as the first-tier rule guiding where New Orleanians built New Orleans in the eighteenth and nineteenth centuries, only to be trumped by drainage technologies in the twentieth century. After Katrina, in the early twenty-first century, topography will drive where New Orleanians demolish New Orleans, and, if heeded, inform how they should reconstruct it.

Geographies of New Orleans
by Richard Campanella
Please order on amazon.com

Riverine New Orleans

To state that New Orleans is inextricably linked to the Mississippi River—physically, historically, culturally, economically—is axiomatic. The river created its underlying terrain, drew indigenous and colonial attention to the site, connected the city to the world, nurtured its crops and industries, sustained it, threatened it, unified external influences, diffused internal traits, and conveyed cargo handled here to and from points worldwide. New Orleanians imbibe the waters of the Mississippi every day from cradle to grave: the river is literally part of their lives. That the Crescent City is the first and last major city on the Mississippi, intentionally positioned at the point of adjacency between the southern seas and the North American interior, renders it that much more an urban scion of the Father of Waters. New Orleans "has strong advantages from its own situation," wrote Thomas Ashe in 1806. "It stands on the very bank of *the most perfect course of fresh water navigation in the world*…one hundred miles from the sea,"[71] accessible to all the rest of the maritime world. This chapter assesses the magnitude and significance of this continental drainage and describes selected "roles" it plays upon New Orleans. The discussion emphasizes riverine influences upon the physical environment, including natural resources and infrastructure, rather than upon New Orleans' political, cultural, and economic experiences. It concludes by addressing the modern city's disturbing conundrum: with a resource as august and invaluable as the Mississippi, why is New Orleans declining economically?

Magnitude

Gauging the influence of the Mississippi River on New Orleans starts with a snapshot of the river's sheer magnitude. Alas, the Mississippi's very dynamism obscures its exact measurements, and even its "true" course. Because the wending flow constantly erodes banks, builds battures, shifts sandbars, creates and cuts off meanders, and extends its delta (often with the help of man, intentional and otherwise), measurements of the river's length vary from under 2,322 to over 2,775 miles. Signs posted at the Lake Itasca headwaters in Minnesota claim that the river runs 2,552 miles to the Gulf of Mexico. This chapter uses 2,340 miles as the length, based on a published U.S. Geological Survey source. Width, too, can be deceiving, as a slight change in stage (water level) may expand or contract the river's surface width considerably. Shallow sections of the upper river may span a mile, while deeper sections of far greater volume in the lower river sometimes measure less than 2,000 feet across. Zooming in to finer scale, complexity defines the river's physics. Water may flow south in one mile; north the next. In straight sections, it flows faster in mid-channel, where friction impedes it less, than along the bottom and banks. In meanders, the deepest trench (thalweg) and highest velocity veer outwardly and erode the bank ("cutbank"), while water on the inside of the meander ("point bar") slows, deposits sediment, and diminishes water depth. Water closest to the surface usually flows fastest, as it rides the steepest gradient to the mouth; in other places, the current reverses directions and whirls treacherously. Velocity and the associated ability to transport sediment vary with flood stage, bottom roughness, particle size, and channel geography; these factors plus the adjacent landscape and distance-to-mouth in turn influence the slope of the river. Gravity guides the river inextricably toward steeper gradients, leading to channel jumps and new routes toward the gulf. Further complexity comes in the form of the tributaries periodically joining the channel, each of which drains waters of varying volumes gathered under differing circumstances. The Mississippi may be thought of as a series of segments whose character changes as it garners new influences in its path toward the sea.

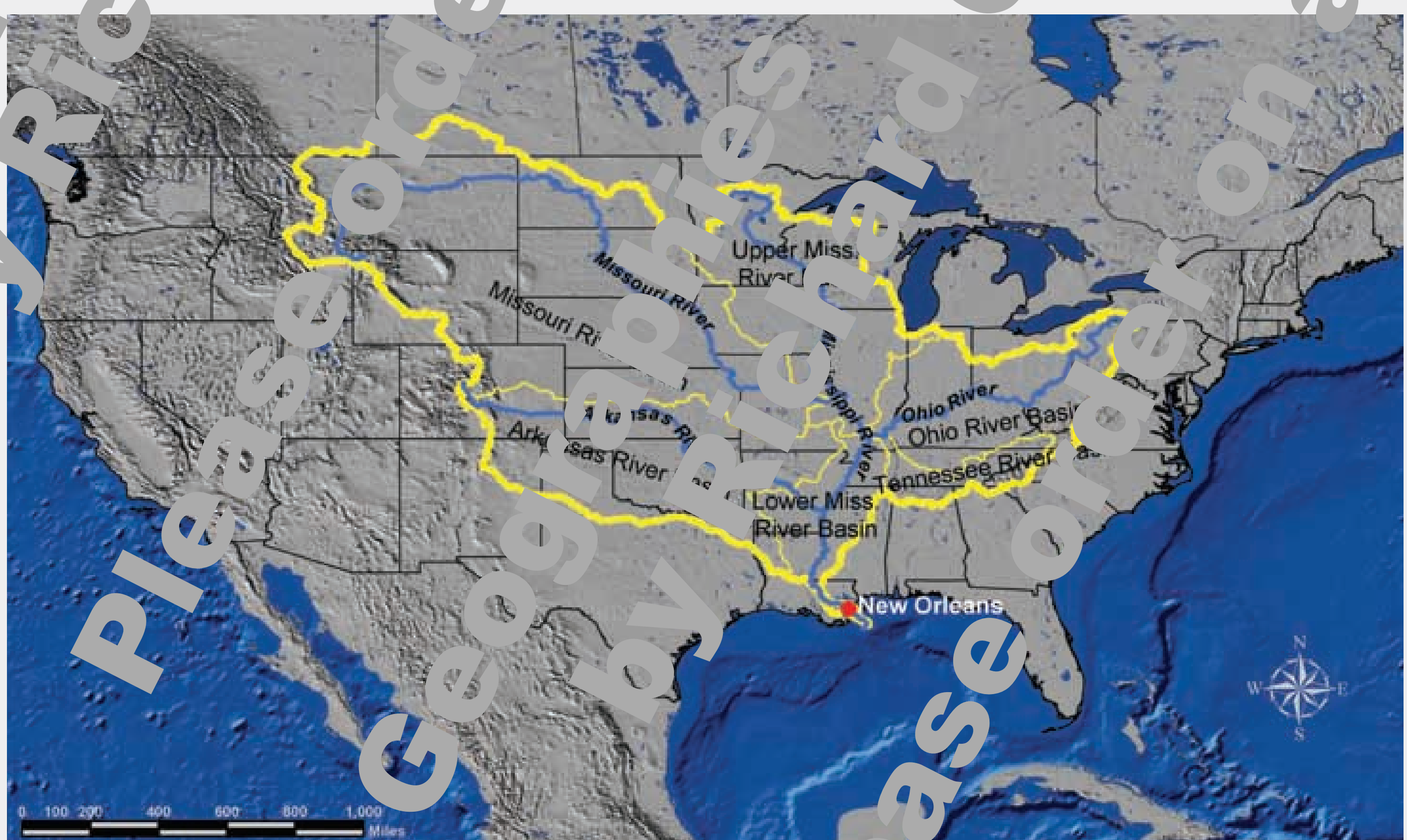
Starting with its traditionally recognized origin in 1,475-foot-high Lake Itasca, the incipient Mississippi drains the forests and prairies of north central Minnesota, forming a placid current of clear, cold water at times only a few dozen feet wide. The U.S. Geological Survey measures an average of 443 cubic feet per second (CFS) of water at its gauge at Winnibigoshish Dam, seven[illegible] miles from the headwaters, the equivalent of a twenty-one-by-twenty-one-foot wall of water passing a line in one second.[72] (This volume will expand by a factor of one thousand by the time it reaches New Orleans, about ninety days hence.) After passing the Twin Cities, where the flow measures 11,786 CFS, the river augments with the contributions of the rivers St. Croix, Wisconsin, Rock, Des Moines, and Illinois, plus scores of smaller tributaries. As the river separates the states of Minnesota, Iowa, and Missouri from Wisconsin and Illinois, it reaches some of its widest spans—over two miles wide at natural Lake Pepin and four miles at manmade Lake Onalaska—but otherwise maintains a fairly consistent character.

Now averaging 105,812 CFS, the river undergoes its first major transformation at its confluence with the 2,565-mile-long Missouri River, which drains [illegible],124 CFS from a basin extending 529,000 square miles westward. The Missouri, born as Red Rock Creek in the Montana Rockies, accounts for nearly half of the entire Mississippi River Basin in terms of areal extent, and actually outranks the Father of Waters in length by two hundred miles. Though it contributes only 13 percent of the Mississippi's eventual maximum flow, the Missouri brings to the system the lion's share of its sediment load, eroded from Midwestern farmlands and Western mountains and prairies. By the time the Mississippi passes St. Louis, immediately below the confluence, it has transformed to a muddy and turbulent river of 191,136 CFS.

[71] As quoted in Jane Louise Mesick, *The English Traveller in America, 1785-1835* (New York, 1922), 192 (emphasis added).

[72] All flow rate data were extracted from the U.S. Geological Survey Office of Surface Water streamflow database, available at http://waterdata.usgs.gov/nwis/rt, and computed to determine average annual flow rates at selected gauges for as many years as data had been collected. Analysis conducted September 2003.

The 1,243,700-square-mile Mississippi River Basin drains 41 percent of the continental United States and 15 percent of the North American continent; thirty-one states and two Canadian provinces partially or fully drain into the Mississippi. The outflow discharges entirely along coastal southeastern Louisiana, 70 percent via the Mississippi, 30 percent via the Atchafalaya. *Maps by author; data from USGS and ESRI.*



Mississippi River viewed from the loess bluffs of Natchez, Mississippi. The river here reaches its peak single-channel volume, averaging over 600,000 CFS and surpassing 1,000,000 CFS in high-water years—a theoretical foot-thick wall of water 1,000 feet wide and 1,000 feet high passing every second. *Photograph by author, 2004.*

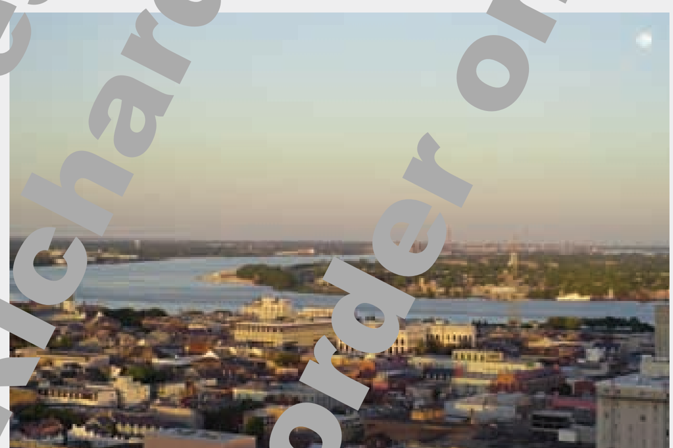
An even greater transformation occurs at Cairo, Illinois, "the vortex of the United States,"[73] where the Ohio River joins the Mississippi. The geological and hydrological significance of this locale cannot be overstated: it marked both the southern edge of glacial maximum during the Ice Age, and the northern tip of the Mississippi Embayment, the great rift in the earth's crust which formed the Mississippi Valley. Encroaching ice sheets sculpted the channels of the Missouri and Ohio to flow into the hitherto meager Mississippi, dramatically increasing its flow and essentially creating the lower river channel and Louisiana deltaic plain. The glaciers have long since retreated and the Mississippi Embayment has filled with sediment, but the Ohio River confluence continues to transform the Mississippi into a completely different river—so much so that scientists and engineers almost universally use terms to distinguish between the "upper" and "lower" Mississippi. The upper Mississippi flows in a relatively well-defined channel through a bluff-lined valley one to six miles wide; the lower Mississippi, on the other hand, meanders broadly across a pancake-flat alluvial plain twelve to twenty miles wide. The upper river runs beneath adjacent hills and collects their runoff; the lower river usually flows above its immediate surroundings, both shedding water into distributaries as well as collecting it via tributaries. The upper river, immediately above Cairo, carries 208,174 CFS; the lower river more than doubles to 484,609 CFS with the addition of its single greatest tributary. In sum, the Ohio River confluence at Cairo turns the Mississippi from a significant regional waterway into a world-class, continental-scale drainage. "The modest maiden hiding within its walls becomes a brazen exhibitionist riding on top of the world," wrote Willard Price of this metamorphosis. "The Mississippi changes its sex at Cairo. The charming upper river is unmistakably feminine[;] the big brute of a lower river is just as certainly masculine."[74]

Despite its upraised stature, the lower Mississippi still acts as a water collector, with the addition of the Arkansas River's 39,743 CFS and accompanying sediment load from its headwaters in the Colorado Rockies. By the time it flows beneath the loess bluffs of Vicksburg and Natchez, the Mississippi River reaches its peak single-channel volume, averaging 602,724 CFS, though it easily surpasses 1,000,000 CFS in high-water years—a theoretical foot-thick wall of water 1,000 feet wide and 1,000 feet high passing in one second.

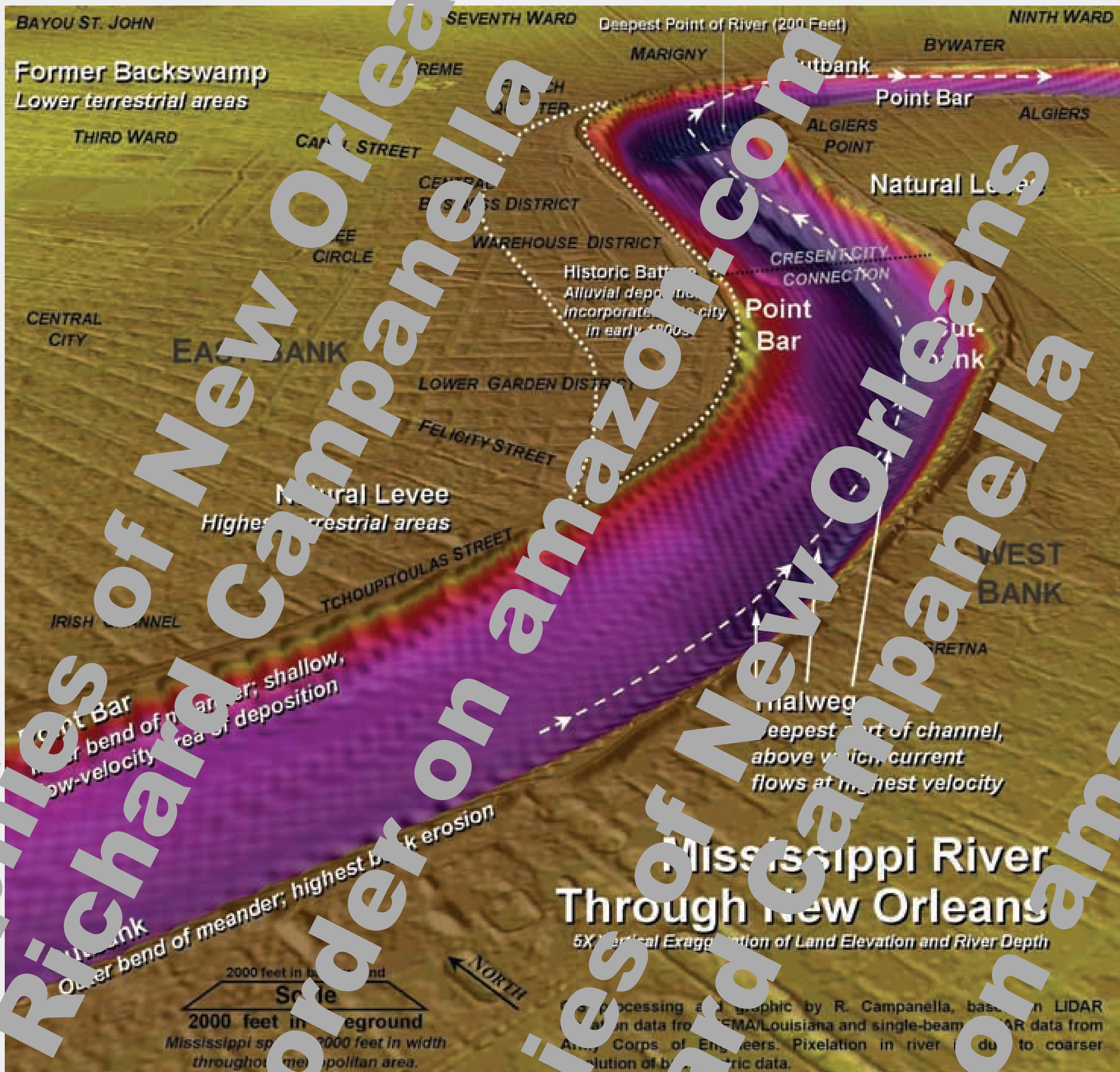
About fifty river miles south of Natchez, the Mississippi changes character for a third time. At this climactic point, the "funnel" formed by the Red River Valley to the northwest and the Mississippi Valley to the north join together in the shape of a narrow spout. The New Mexico-born Red River, with a present-day flow of 30,797 CFS, once flowed into the Mississippi at the top of a meander loop (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, Capt. Henry Shreve severed Turnbull's Bend, in the interest of shortening travel time for steamboatsmen, 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 in the other portion, continued to usher the Red into the Mississippi. Little water escaped out the Atchafalaya River distributary because a massive natural logjam clogged the channel. Eight years later, act-

[73] Stephen E. Ambrose and Douglas G. Brinkley, *The Mississippi and the Making of a Nation, From the Louisiana Purchase to Today* (Washington, D.C., 2002), 161.

[74] Willard Price, *The Amazing Mississippi* (London, Melbourne, Toronto, 1962), [illegible].



The Mississippi River at the French Quarter measures 2,000 feet wide and two hundred feet deep, the river's deepest point. Its stage (height) varies from as low as eight to nine inches to as high as twenty feet above the mean level of the Gulf of Mexico. The river has played the roles of creator, provider, and threat to New Orleans: creator of land; provider of water, sediment, and access; threat by flooding, pollution, channel-jumping, and as an invasion route. It will remain the city's most valuable resource into the twenty-first century, as fresh water becomes an increasingly valued resource. *Photograph by author, 2004.*



Uptown New Orleans sits on a point bar—the concave side of a river meander where the current slows and deposits sediment. Across the river is the cutbank, where the river runs faster and deeper (thalweg), and erodes the bank more aggressively. Past the French Quarter, the thalweg swings across the channel, eroding the east bank and accreting the west. *GIS processing by author based on data from FEMA, State of Louisiana, and Army Corps of Engineers.*

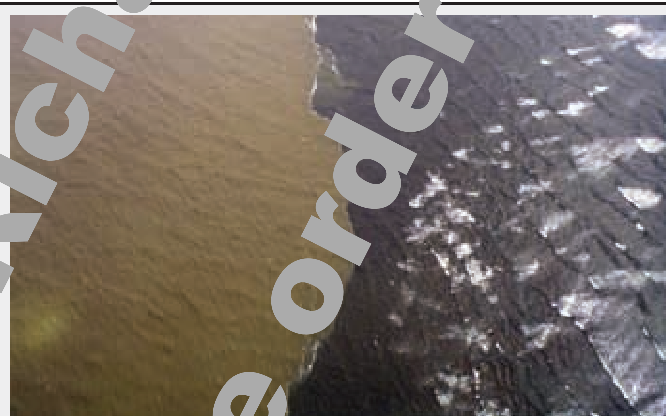
ing in the interest of navigation and development, the state of Louisiana started clearing the thirty-mile-long blockage of the Atchafalaya, unknowingly providing the Mississippi two characteristics that physics dictates it will seize: a shorter path and steeper gradient to the sea. The cleared Atchafalaya allowed increasing quantities of both the Red and the Mississippi to flow down the 142 relatively steep miles of the Atchafalaya, rather than the 315 relatively flat miles of the Mississippi. By the mid-twentieth century, the Atchafalaya had tripled its share of Mississippi water and seized all of the Red's. Scientists by that time recognized that the Father of Waters would eventually jump channels—substantially, possibly entirely, around 1975—abandoning New Orleans and converting Louisiana's invaluable river corridor into an elongated and increasingly 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 government-approved seventy-thirty ratio, which may be adjusted to alter the stage of either river for flooding or navigation reasons. Thus, while the Mississippi peaks in the Vicksburg-Natchez section at about 602,724 CFS, it runs an average of 465,206 CFS by Baton Rouge, having distributed 30 percent into the Atchafalaya distributary (but gaining back 7-8 percent courtesy of runoff from the Tunica Hills region north of Baton Rouge). The Old River Control Structure represents one of the most Herculean engineering projects in history, emblematic of both the brilliance and folly of man's alteration of the environment to suite his needs.[75]

Below Baton Rouge, the Mississippi River departs the broad flood plain at the bottom of an alluvial valley and enters its upper deltaic plain.[76] "As the traveler proceeds down the Mississippi," New Orleans Mayor Martin Behrman once observed, "the river seems to grow higher as he descends."[77] It is no illusion: near the West Baton Rouge-East Baton Rouge-Iberville parish lines, the Mississippi River leaves behind the valley "walled" by the meager Pleistocene uplands east of Baton Rouge and west of Lafayette, and thence flows above the landscape, buttressed by natural levees rising ten to fifteen feet above the swamps. With manmade levees adding another fifteen to twenty feet of elevation, the river's immediate flanks make up the most prominent topographical feature in the upper deltaic plain. In its final two hundred miles, the Mississippi River averages 2,000-3,000 feet wide, runs fifty-four to two hundred feet deep at its deepest point per river mile,[78] and flows at slightly below the rate gauged at Baton Rouge. There are no more tributaries in this deltaic region (the last one joins the river in North Baton Rouge); this veritable *cordillera* is a shedder of water, not a collector. Former distributaries such as Bayou Manchac and Bayou Lafourche have been all but sealed off, while the broad Bonnet Carré crevasse between the river and Lake Pontchartrain was wisely engineered into an emergency spillway for floodwater—but only after the Great Flood of 1927 exposed the danger of relying solely on levees for flood control.

At River Mile 115, the Mississippi River enters the New Orleans metropolitan area and twists through it for the next twenty-seven miles. Thirteen of those urban river miles actually abut Orleans Parish, and for only 4.[illegible] miles does Orleans Parish envelop both banks of the river. The metropolitan section of the river is especially wending, forming two prominent point bars on the east bank and three on the West Bank, plus three river meanders of about [illegible] degrees which have challenged navigators for three hundred years. Ninety-five miles above the mouth sits the original city of New Orleans, where, coincidentally, lies the deepest point of the entire river, almost two hundred feet deep depending on river stage and bed load conditions. The rate of flow through New Orleans typically ranges from 450,000 to [illegible],000 CFS at normal river stage, but can triple that volume during high water: it swelled to a frightening 1,557,000 CFS during the Great Flood of 1927. Since consistent measurements have been kept, river stage in New Orleans has run as low as 0.71 feet above mean gulf level (February 11, 1977) and as high as 19.98 feet (February 10, 1950), averaging about 10 feet above the sea.[79] This means that the river surface is almost always higher than 56 percent of greater New Orleans, usually higher than 95 percent, and occasionally higher than 99.5 percent of the land surface (everything except the artificial levees).[80] Such is the sheer physical dominance of the Mississippi River on the cityscape of New Orleans.

Once past greater New Orleans, the river makes one last great meander at English Turn before straightening out and speeding up through Plaquemines Parish to the Gulf of Mexico. A wild, frontier-like ambience in both the physical and human environment prevails in this isolated region; one senses the culmination of a great natural process and the proximity of the ragged edge of a continent. At Head of Passes—River Mile 0—the channel trifurcates into a birdfoot-shaped embouchure known as the Balize Delta or Plaquemines Complex. In terms of spatial extent, the modern Mississippi River delta is not the largest on earth; the Ganges and Mekong span about triple the size, and the Amazon's delta is sixteen times larger. But it is probably the world's most outstanding example of an elongated, river-dominated delta, as opposed to those dominated by waves, tides, or combinations of the three factors. Deltas are dominated by rivers when the flow of fresh water and sediment is substantial and the receiving sea is slow-moving and placid, as is the Gulf of Mexico. The resulting formation is a "well-developed delta plain with several distributaries projecting seaward in a digitate, 'bird's foot' configuration."[81] The Mississippi's birdfoot formation comprises six subdeltas, numerous splays and lobes, and three major passes: Southwest Pass (50 percent of flow and

[75] John McPhee, *The Control of Nature* (New York, 1989), 3-[illegible]; Army Corps of Engineers, New Orleans District, *Old River Control* (Agency booklet, 1999).
[76] The line between the Mississippi's alluvial valley and deltaic plain may be drawn as far north as Old River, where the Atchafalaya becomes the Mississippi's first distributary, to as far south as the Lafayette-to-Baton Rouge area, where the last bluffs disappear and the river is free to meander widely.
[77] Martin Behrman, "New Orleans—A History of Three Great Public Utilities: Sewage, Water, and Drainage," Convention of League of American Municipalities (Milwaukee, WI, 1914), 1.
[78] Computed from 1992 bathymetric and bankline data from Bayou Manchac to Head of Passes. Analysis by author, 2003.
[79] Earlier stage data, held to different standards, record a low of –1.6 feet in 1872 and a high of 21.27 in 1922. U.S. Army Corps of Engineers, New Orleans District, Water Control Section, *Stage Data: Mississippi River At New Orleans, LA (Carrollton)*, http://www.mvn.usace.army.mil/cgi-bin/watercontrol.p1?01300.
[80] Percentages computed from LIDAR digital elevation models of terrestrial surface of metropolitan area from 90° 15' West, 29° 53' North to 89° 56' West, 30° 03' North (roughly from Westwego to Little Woods). This area is [illegible]4 percent above sea level, 49 percent below sea level, and 7 percent at sea level.
[81] Richard A. Davis, Jr., *The Evolving Coast* (New York, 1994), 135-44.



This photograph, taken from an aircraft near the mouth of the Mississippi, illustrates the stark interface between sediment-laden river water and the clear, saline Gulf of Mexico. From this interaction emerged the terrain of New Orleans over the past 5,000 years. *Photograph by author, 2004; aircraft courtesy SouthWings, The Nature Conservancy, and CBR.*

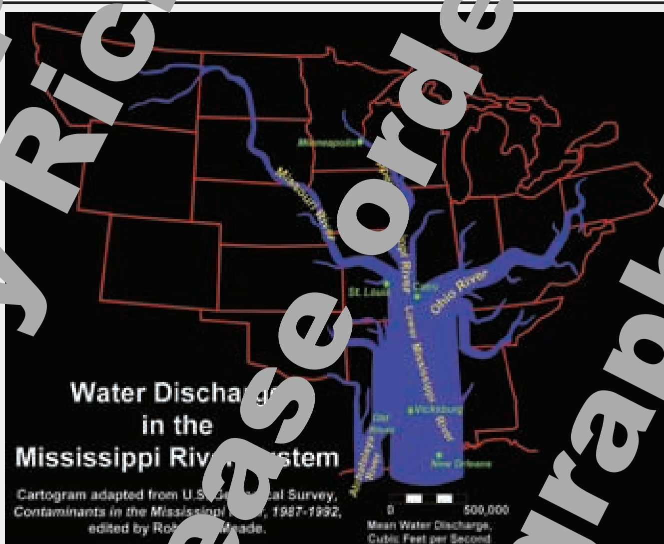
the route of most navigation activity), South Pass (20 percent), and Pass à Loutre (30 percent), which branches into North and Northeast Pass. It is the seventh delta complex to have roamed across southern Louisiana in as many millennia, flooding, depositing, jumping channels, and building new land as earlier sediments sink and erode to the sea. The sediment load, discharged to the continental shelf, extends the lower deltaic plain into a subaqueous delta amid a sediment plume visible from space. In this great estuary the telltale waters of the Mississippi, which reflect with unrelenting accuracy myriad environmental alterations in the North American interior, intermix with the sea. "The line of demarcation between the yellowish-brown water of the river, and the clear green water of the sea," wrote Joseph Holt Ingraham in 1835, "is so distinctly defined, that a cane could be laid along it."[82]

Nomenclature

Measurements of the Mississippi River understate the true magnitude of the natural phenomenon flowing through New Orleans, for what we designate with that indigenous appellation is really a subset of a much larger system. The Mississippi River Basin drains an area spanning 1,750 miles at its widest point and 1,450 miles north to south, fully 15 percent of the entire North American continent and 41 percent of the continental United States. Thirty-one states and two Canadian provinces partially or fully drain into the Mississippi, whose basin, covering 1,243,700 square miles, is surpassed only by those of the Amazon and Congo. Within this watershed are countless stream sub-basins feeding into hundreds of river sub-basins, these into scores of larger river sub-basins, and eventually into three major river sub-basins: one from the west (the Missouri), one from the north (the upper Mississippi), and one from the east (the Ohio). These three major sub-systems merge within a two-hundred-mile stretch of river between St. Louis and Cairo. There is no dispute that the great river flowing below Cairo to the Gulf of Mexico is the *bona fide* Father of Waters. Above Cairo, however, where the three tributaries unify waters drained from a vast dendritic network, we rather arbitrarily declare the north branch, originating in Minnesota, to be *the* Mississippi River. Why?

Perhaps its centrally located position and ordinal, meridian-following orientation convinced mapmakers that it constituted a single hydrological entity with the lower Mississippi. To this day, a popular but highly erroneous notion holds that rivers flow in a north-to-south direction.[83] Perhaps topography played a role: the upper Mississippi drains the same relatively flat forested terrain that also characterizes the lower Mississippi—together forming "the great longitudinal trough of North America"[84]—whereas the Missouri and Ohio tributaries are born in distant mountainous environments off to the west and east. But the real reason is historical. Because early French explorers—Jacques Marquette and Louis Joliet in 1673 and René Robert Cavelier de La Salle in 1682—first encountered the river system from the Great Lakes region downriver toward the Gulf of Mexico, that route struck them as a single, cohesive hydrological unit. Historian Timothy Severin noted that early French traders heard the Algonkian word *Mississippi*, loosely translated as "Big Water" or "Father of Waters," from Chippewa tribesmen in the northern territory and "carried it downstream with them,"[85] implying that the defining element of the river's route was the Frenchmen's own exploration down it. This impression was passed on to cartographers, who depicted it in turn-of-the-eighteenth-century maps under sundry names—"Immaculate Conception," *Buade ou Frontenac*, "Colbert," "St. Louis," "Louisiana," and every conceivable orthography of "Mississippi." Le Page du Pratz attested to the direction of discovery and consequent nomenclature in his 1774 *History of Louisiana*:

> The first discoverers of this river by the way of Canada, called it Colbert, in honour of that great minister [Jean Baptiste Colbert, financial minister for Louis XIV]. By some of the savages of the north it is called Meact-Chassipi, which literally denotes, The Ancient Father of Rivers, of which the French have, by corruption, formed Missisippi. Other Indians, especially those lower down the river, call it Balbancha; and at last the French have given it the name of St. Louis.[86]



Three river channels—the Missouri, the upper Mississippi, and Ohio—unite between St. Louis and Cairo to form the great continental drainage that flows past New Orleans. For historical reasons, we designate the middle channel as "the" Mississippi River, but as this cartogram illustrates, the Ohio contributes more water, while the Missouri runs for the longest distance. As traditionally defined, the Mississippi River runs about 2,340 miles from its Lake Itasca headwaters to its discharge in the Gulf of Mexico, where it flows at about 500,000 cubic feet per second. *Graphic by author based on research by Meade, USGS.*

[82] Joseph Holt Ingraham, *The South-West by a Yankee*, 2 vols. (New York, 1835), 1:62.

[83] See Edward Fontaine, "A Lecture on the Peculiarities of the Physical Geography of the Mississippi River and Its Delta" (Washington, D.C., 1874), 5, for a novel circa-1874 explanation of the Mississippi's north-south orientation, involving the centrifugal force of the rotating Earth.

[84] Justin Winsor, *The Mississippi Basin: The Struggle in America Between England and France 1697-1763* (Cambridge, MA, 1895), 8.

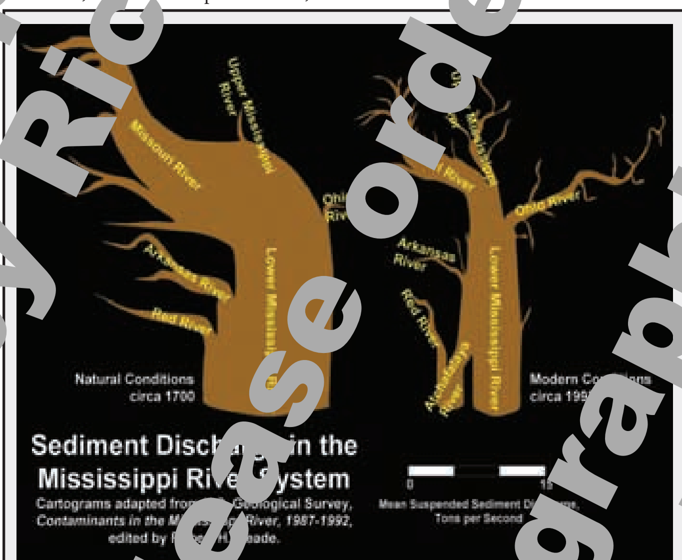
[85] Timothy Severin, *Explorers of the Mississippi* (New York, 1968), 4 and 10.

[86] Le Page du Pratz, *The History of Louisiana*, ed. Joseph G. Tregle, Jr. (Baton Rouge, 1976), 121.

By the 1710s-1720s, French maps and English derivations identified the source of the Mississippi as a series of small hypothetical lakes west of the Great Lakes, and the route of the Mississippi as the channel flowing from them southward to the Gulf of Mexico.[87] All other channels, no matter how significant, were perceived as tributaries. Had early explorers sailed down the Ohio to the Gulf of Mexico, or from the gulf up the Missouri, we may well describe either of those routes as the continent's greatest river (though it would not have carried the name *Mississippi*, since this indigenous word came from the northern region). There is no compelling hydrological or geological explanation justifying the designation of the Minnesota-to-Cairo river as the main trunk of the Mississippi. If sheer length, distance from mouth, or sediment load were the criteria, the Missouri River-to-gulf route would form the Mississippi River. (Even as conventionally defined, the Missouri is longer than the Mississippi by two hundred miles). If water volume were the criteria, then the Ohio River-to-gulf route would be bestowed with that name. (The Ohio discharges 281,000 cubic feet per second into the Mississippi at Cairo, more than triple the Missouri's volume and roughly half that of the Mississippi at *its* mouth.[88]) If hydrology or geology were the criteria, then the Mississippi River would almost assuredly describe solely the Cairo-to-Gulf channel—that is, what is generally called the "lower Mississippi River" today.

[87] See, for example, Gerard van Keulen's *Carte de la Nouvelle France où se Voit le Cours des Grandes Rivières de S. Laurens & de Mississipi* (1718), Herman Moll's *A New Map of the North Parts of America Claimed by France* (1720), and Daniel Coxe's *A Description of the English Province of Carolana* (1727). Original maps archived at The Historic New Orleans Collection and displayed at the "Charting Louisiana" exhibit in the Williams Research Center, September 2003.

[88] J.C. Kammerer, "Largest Rivers in the United States," *U.S. Geological Survey Water Fact Sheet*, Open-File Report 87-242, 1990.



While most water enters the lower Mississippi River via the Ohio, most sediment comes from the Missouri and other western sources. Dozens of dams erected on western tributaries during the twentieth century now trap much of it upstream. In 1846, the river at New Orleans bore 800 milligrams of sediment per liter; today, the figure is around 125 mg/l (see text for details). The change is visible to the naked eye: waters that were once an opaque rusty brown are now a translucent, cloudy gray. *Graphic by author based on research by Meade, USGS.*

This is not just an interesting (and, to some, heretical) question of nomenclature.[89] Considering the Mississippi River as the culmination of a vast watershed puts New Orleans astride not "just" a 2,340-mile river, but a 14,500-mile network of interconnected navigable waterways and a much larger web of smaller tributaries. Those waters carry commerce and culture as well as sediment, biota, and chemicals to New Orleans, and avail to the city an equally large area to which it can export its attributes, and convey those originating elsewhere. If rivers are "regional bonds,"[90] bundling together waterborne routes with parallel roads, trails, railroads, and population clusters, and if the Mississippi River is viewed as a vast network of waterways spanning an immense basin, then New Orleans is uniquely bonded to the heart of an entire continent. The roles of the river discussed in the next section should be considered as not just the influences upon New Orleans of the single channel christened "Mississippi," but of this much grander system. It is no wonder that the magnitude of this system, only fully understood after the Lewis and Clark expedition and ensuing explorations, inspired commentators such as Charles Sealsfield (1828) to wax eloquently on the future of New Orleans:

> Standing on the extreme point of the longest river in the world, New Orleans commands all the commerce of the immense territory…exceeding a million square miles. You may travel on board a steam-boat of three hundred tons [for] 1,000 miles from New Orleans up the river; 1,500 miles up the Arkansas river; 2,000 miles up the Missouri and its branches; 1,700 miles on the Mississippi to the falls of St. Anthony; the same distance from New Orleans up the Illinois; 1,200 miles on the big Wabash; 1,000 on the Tennessee; 1,300 on the Cumberland, and 2,300 miles on the Ohio up to Pittsburgh. Thus New Orleans has in its rear this immense territory, [plus] the coast of Mexico, the West India islands, and the half of America to the south, the rest of America on its left, and the continent of Europe beyond the Atlantic. *New Orleans is beyond a doubt the most important commercial point on the face of the earth.*[91]

Roles of the Mississippi River in New Orleans

The Mississippi River plays roles of *provider*, *creator*, and *threat* to the physical landscape of New Orleans.

River as Provider — Sundry resources arrive to New Orleans via the Mississippi River, as they have for centuries. Breezes coming off its 2,000-foot-wide surface provided New Orleanians of the eighteenth and early nineteenth century the sole refuge from the stagnant heat of a summer eve. Fuel arrived on its surface: a visitor observed in 1826 "much driftwood afloat on the river, even large tree trunks, [which] Ne-

[89] Others have made this observation: see Severin, *Explorers of the Mississippi*, 5-6, and Norah Deakin Davis, *The Father of Waters: A Mississippi River Chronicle* (San Francisco, 1982), 1-2.

[90] Edward L. Ullman, "Rivers as Regional Bonds: The Columbia-Snake Example," *Geographical Review* 41 (April 1951): 210.

[91] Charles Sealsfield, *The Americans As They Are; Described in A Tour Through the Valley of the Mississippi* (London, 1828), 165-66 (emphasis added).

groes in canoes were engaged in bringing… to shore, where it serves the people on the *levée* as firewood.”[92] Maj. Amos Stoddard commented in 1812 on its fisheries resources:

> The Mississippi is not remarkable for good fish. [The deltaic] part of it, however, furnishes plenty of excellent eels, shrimps, and a species of small sturgeon [as well as a kind of fresh water sheep-head, and likewise the carp or buffalo fish…. Cat fish abound in all parts of the Mississippi. Some of them weigh one hundred and seventy pounds…. Some [alligators] in the Mississippi are fifteen feet long [and] ascend that river to the Arkansas.[93]

To this day, local fishermen haul enormous catfish from the river within sight of St. Louis Cathedral, and, despite the contaminants bio-concentrated in their aged flesh, take home the great bottom-dwellers for the frying pan.

In terms of critical resources imparted in colossal quantities, the Mississippi River is the exclusive provider to New Orleans of two: fresh water and sediment. The two most basic elements of the planet, water and rock, are extracted *en masse* from a million square miles of interior land and routed through New Orleans to the sea. During normal stage, roughly three hundred billion gallons of H_2O flow past Jackson Square every day, accompanied by about one billion pounds of sediment. The Mississippi ranks as the seventh largest river in the world in terms of both these discharges.[94] The first is tapped liberally and easily by the city to satisfy its everyday needs, the second is a bit more challenging to extricate and not needed as regularly, but ultimately just as critical to the survival of the region.

So abundant and reliable is the supply of fresh water in New Orleans that residents may not appreciate its scarcity in urban areas across the nation and globe. A water surplus in the Crescent City and a shortage in cities as close as Florida,[95] and as far as the Mideast, have led some to ponder the economics of exporting Mississippi River water as a commodity. The water is here, the shipping lanes and port facilities are established, and the technology is available; the only obstacle is cost, and if present trends continue, willing buyers may someday call. Until then, New Orleans will happily satisfy its own water needs courtesy of the Mississippi, as it has since the earliest days of human inhabitation of the area.

For most of its first century, New Orleanians obtained their potable water by scooping it from the river themselves or purchasing it from street vendors at one *picayune* for four buckets. Homemakers would then store the water in earthen jars and remove the sediment by means of stone, alum, or charcoal filters. “When filtrated, it is transparent, light, soft, pleasant, and wholesome,” reported Stoddard in 1812. “The salubrious quality of its water is attributed to the nitre and sulphur [and the river’s] deep and rapid current…. As it is precipitated from the cold regions, it tempers the fervid atmosphere of the lower Mississippi, and renders it more healthful.”[96] Water for other domestic uses, needed in greater quantity but not in high quality, came from shallow, muddy wells dug in courtyards. Beyond the banquettes, the great river flowing just one block from the city went practically unutilized for lack of a mechanized system to pump it over the levee and distribute it throughout the city. In 1810, a system worthy of Biblical times was attempted on the levee at the foot of Ursulines Street, in which river water was pumped manually by slaves into a reservoir and distributed through hollow cypress logs to subscribers. That primitive system was vastly improved by the design of famed architect Benjamin H.B. Latrobe, consisting of a steam pump mounted in a three-story pumphouse, which drew water from the Mississippi, stored it in raised reservoirs, and distributed it through a superior network of cypress pipes to residential households. Over a decade in the making and fraught with legal and other problems, Latrobe’s waterworks was finally completed three years after the architect’s death to yellow fever, and served the city well from 1823 to 1836. The growth and spread of the antebellum boomtown soon challenged the capacity of the system, helping spawn a number of private water companies overseen by the city. The Commercial Bank of New Orleans operated the system from 1836 to 1869, after which the city took over until 1878, when the city deeded the system over to the New Orleans Water Works Company. Its monopoly status, upheld in court, precluded the rise of competing systems. By the 1880s, about 8,000,000 gallons per day were pumped through seventy-one miles of cast-iron pipe, creating a small domestic water supply for those few who were connected to the system. The lack of a modern purification processes, plus mismanagement and unreliability, rendered the system inadequate and forced residents to satisfy their potable water needs through what one local-color writer described in 1893 as “one of the strangest and most distinctive features of New Orleans[:] containing-tanks for rain-water in almost every door-yard.”

> Rising above the palms, the vine-trellises, and the stately magnolias are these huge, hooped, green cylinders of wood. They suggest enormous water-cloths on end and with the tops cut off…. Nine-tenths of the water used for cooking and drinking is this cistern water.[97]

Into the 1890s, “practically the whole city depended on rain water caught on their roofs and stored in cisterns as the source of drinking water.”[98] This meant that, during

[92] Duke of Saxe-Weimar-Eisenach Bernhard, *Travels by His Duke Bernhard of Saxe-Weimar-Eisenach Through North America in the Years 1825 and 1826*, ed. William Jeronimus, ed. C.J. Jeronimus (Lanham, NY, and Oxford, 2001), 20.

[93] Major Amos Stoddard, *Skteches, Historical and Descriptive, of Louisiana* (Philadelphia, PA, 1812), 163-64.

[94] In terms of water discharge, the Amazon ranks first, followed by the Zaire, Orinoco in Venezuela, Ganges, Yangtze, and Yenisey in Russia. In terms of sediment discharge, the Amazon is first, followed by the Yellow, Ganges, Yangtze, Irrawaddy in Burma/Myanmar, and Magdalena in Columbia. As cited in B.A. McKee, “RiOMAR: The Transport, Transformation and Fate of Carbon in River-Dominated Ocean Margins,” Report of the RiOMAR Workshop, Tulane University, New Orleans, LA, November 1-3, 2001, 4.

[95] While New Orleans watches a half-million cubic feet of freshwater pass by every second, the Gulf Coast city of Tampa, Florida, just a few hundred miles away, struggles with a costly and problematic desalination plant to satisfy its water needs.

[96] Stoddard, *Sketches, Historical and Descriptive*, 164.

[97] Julian Ralph, “New Orleans, Our Southern Capital,” *Harper’s New Monthly Magazine* 86 (February 1893): 370.

[98] Water L. Dodd, *Report of the Health and Sanitary Survey of the City of New Orleans* (New Orleans, 1918-1919), 94.

dry spells, many residents of this riverine city actually suffered water famines, particularly the poor living in the back-of-town. During droughts, water was sometimes "delivered" to residents simply by pumping it through the open gutters. This tactic, in 1883, serendipitously provided another Mississippi River resource to New Orleans: "Many of the gutters are alive with small fish and river shrimp, and they furnish a harvest to the boys who catch them…."[99]

It was the Progressive municipal improvement era of the turn-of-the-century that finally brought a full-scale modern municipal water system (as well as a drainage and sewerage system) to New Orleans. Research conducted at Audubon Park in the 1890s helped determine optimal methods for purifying the sediment-laden waters of the Mississippi, debunking those who claimed that only artesian wells or Lake Pontchartrain could provide potable water. The New Orleans Sewerage and Water Board, established in 1899, sited the new waterworks plant in the extreme upriver neighborhood of Carrollton. The location was selected for a number of reasons: it was, at the time, the rural edge of the city, upstream from sources of urban pollution and above the salt-water intrusions occasioned by extremely low river stages or hurricane-induced gulf surges.[100] The site also provided the maximum amount of head for distribution to homes, because it tapped the river at a slightly higher stage that in other parts of the city. (The river gains about 1.5 inches in stage per river mile heading upriver in the metro area; thus the river at the Carrollton intake averages over a foot higher than its stage at the French Quarter.) Locating the plant 3,000-4,000 feet from the river kept it out of the way of shipping activity, wharves, and railroads, while siting it just within the Orleans Parish line kept it within local government control, even if it did supplant some residential blocks.

The Carrollton Water Works Plant, started in 1905 and opened in 1908, drew water from the Mississippi by an intake pipe and pumped it into a "head house," the controlling node at the center of a series of reinforced concrete reservoirs. The water then passed slowly over the "grit reservoir," where its coarsest particles settled out, then returned to the head house to be pumped into the "lime mixing reservoir," where lime and sulfate of iron were added for softening. Next, the water returned to the head house to be sent to the "coagulating reservoir," where finer particles of suspended sediment were precipitated out. Finally, the water was again sent back to the head house, strained through sand filters, poured into "equalizing reservoirs," purified further with a small dosage of chloride gas, and stored in the clean water well to await delivery. Eight pumps then propelled the purified water through distribution mains to city residents everywhere except Algiers, which was served through a similar, smaller system on the West Bank. In this manner, modern engineering technology delivered a tiny fraction of the runoff of the North American interior—33,000,000 gallons per day in the 1910s, or 0.01 percent of normal river volume—into the kitchens and courtyards of New Orleanians.[101]

Today, a greatly enlarged Carrollton Plant operates on the same century-old site, drawing water from the Mississippi immediately below the parish line at the Oak Street River Station, and pumping it down Old Ogden Street to the East Bank Water Treatment Plant. The purification process is far more thorough than a century ago but still fundamentally the same, involving coagulants to congeal sediment particles, lime to adjust pH and soften the water, settling basins to remove the sediment, chlorine to disinfect, and sand filtration as the final purification step. The Carrollton Plant and Algiers Plant now yield and distribute [illegible] million gallons of river water per day through 1,610 miles of water mains to 160,000 service connections and virtually the entire population (plus thousands of visitors, who are usually unaware that that they are imbibing the Mississippi River).[102] This means that one [illegible] molecule of every 2,400 flowing past New Orleans is captured for the domestic, municipal, and commercial use of New Orleanians. It is one of the city's greatest and most reliable blessings—cheap, at about $0.03/gallon, and surprisingly high in quality, especially vis-à-vis popular perceptions of the [illegible] Mississippi River. Overall, the Natural Resource Defense Council, which grades municipal tap water on rigorous environmental standards, rated the city's water quality and environmental compliance as "good" for the past few years. The river may soon also satisfy a more upscale market. During his 2002 inaugural speech, Mayor C. Ray Nagin extolled the virtues of the local water supply and unveiled *Crescent City Clear*, river water purified locally and bottled by the venerable Dixie Brewing Company. To the delight of the audience, Mayor Nagin took a swill of Mississippi River water in mid-speech.[103]

Every liter of water gliding past Jackson Square today typically carries fifty to 250 milligrams of suspended sedi-

[99] "Water Famine. Much Suffering in the City for Want of Water for Household Purposes," *Daily Picayune*, October 3, 1883, p. 2, col. 4.

[100] When discharge is low and tides high, gulf waters sometimes intrude 100 miles up the river and into the city's intake pipes, allowing saltwater in the range of one hundred parts per million to be pumped into domestic taps. It happened in 193[illegible], producing "a funny taste in the water" and, according to one journalist, prompting housewives to ask, "I do wish this water wasn't so hard! I can't get a decent shampoo lately [and] I don't know what I'm going to do about my under things." A sand sill installed recently at River Mile 64 now impedes saltwater wedges (which sink, due to their heavier weight) from moving upriver. Brandon Woolley, "Orleanians and Algerians Drink Salt Water For First Time in History," *The Morning Tribute*, September 11, 1930, 1.

[101] Dodd, *Report of the Health and Sanitary Survey*, 96-98; James S. Janssen, *Building New Orleans: The Engineer's Role* (New Orleans, 1987), 26-29; John Smith Kendall, *History of New Orleans*, 3 vols. (Chicago and New York, 1922), 1:113-14, 2:526-29, 2:580-84; George E. Waring, Jr., *Report on the Social Statistics of Cities, Part II: The Southern and the Western States* (Washington, D.C., 1887), 273; and *The New Orleans Book* (New Orleans, 19[illegible]9), 45-46.

[102] Sewerage and Water Board of New Orleans, *The Quality of Our Water*, http://www.swbnola.org/water_in[illegible]m.

[103] "Nagin's Inaugural Speech," *Times-Picayune*, May 7, 2002, National section, p. 6; Martha Carr, and M[illegible] [illegible]allon, "N.O. Tap Water To Be Put To Test," *Times-Picayune*, April 19, 2003, Metro section, p. 1; Natural Resources Defense Council, *What's On Tap? Grading Drinking Water in U.S. Cities: New Orleans, LA*, http://nrdc.org/water/drinking/uscities/contents.asp, page 156; Brobson Lutz, "Water Whirled: How Safe is Our Drinking Water? A Journey Through the Process," *New Orleans Magazine* 36 (November 2001): 45-52.

ment—solid particles of inorganic or organic origin, eroded by means of wind, water, ice, chemical reactions, and other mechanisms. The exact type and quantity depends on topographic relief, lithology, precipitation, temperature, river stage, season, sampling location, and other factors. Some sediment "particles," at the river's farthest reaches, are boulders that settle no farther than the mountainside from which they fell. Others are rocks that tumble in rapids until settling in calmer waters. Finer particles—gravel, sand, silt, clay—are light enough to collect into streams, mobilize in riverbeds, flow into larger tributaries, and finally transfer into the Mississippi River itself. These particles may dissolve completely and move in solution through the river, but most either slide and roll near the river bottom at speeds slower than the water velocity (bed load), or transport through the water column close at full velocity (suspended load). Gravity takes its toll: coarser, heavier particles such as gravel (over 2.0 mm in diameter) and coarser grains of sand (2.0 to 0.05 mm) are more likely to settle far up the river or along its banks, whereas silt (0.05 to 0.002 mm) and clay (under 0.002 mm) are more likely to make it all the way to the Gulf of Mexico. The process of sediment transport is as complex as the river itself, as any change in water velocity (which varies within the column, from mile to mile, and from day to day) affects the river's ability to mobilize or drop its load. The faster the velocity, the more sediment is stirred up and mobilized. When velocity slows, some suspended load drops to the bed load, which slows even more. The suspended load streaming past New Orleans typically comprises very little sand, significant quantities of silt, and even more of clay, while the bed load is the opposite: mostly sand, some silt, and small amounts of clay.[104] Extremely few particles exceeding two millimeters in diameter (that is, gravel) reach New Orleans, since the river sifts out such heavy particles many miles upstream. For this reason, there are no natural rocks in New Orleans nor in any deltaic lands created by the lower Mississippi.

Before the development of the Western frontier, the Missouri River delivered the vast majority of sediment into the Mississippi, with smaller quantities contributed by the two other Rocky Mountain tributaries, the Arkansas and the Red. The forested drainages of the upper Mississippi and Ohio, despite their tremendous water volume, contributed little sediment to the lower Mississippi, which as a whole carried significantly more suspended sediment than it does today.[105] In 1835, for example, Joseph Holt Ingraham reported that "a glass filled with [the Mississippi's] water appears to deposit in a short time a sediment nearly equal to one-twelfth of its bulk."[106] Eleven years later, an investigation conducted on New Orleans's riverfront quantified the sediment load as an average of 890 milligrams per liter.[107] Agricultural development of the Midwest and West in the nineteenth and early twentieth centuries denuded vast forests and grasslands, leaving them vulnerable to erosion and increasing sediment in all Mississippi River tributaries. The environmental damage caused by the loss of this precious topsoil was compounded by the fact that Louisiana could no longer benefit from the Mississippi's increasingly sediment-laden waters, because the river by this time was constrained by artificial levees. Then, in the mid-twentieth century, dams constructed on the sediment-bearing Missouri and Arkansas rivers slowed their waters dramatically and caused them to drop much of their load into reservoirs. Another twenty-seven sets of locks and dams were constructed on the upper Mississippi, and more on other tributaries, with similar effect, trapping roughly [illegible] percent of the system's sediment load. Worse yet, it was the highest-quality sediment—sand, the coarsest and best particles for land-building—that was most likely to end up trapped upstream. Additionally, the increased diversion of Mississippi water into the Atchafalaya (now engineered to a stable 30 percent by the Old River Control Structure) routed even more sediment away from New Orleans. As a result, the Mississippi today carries past New Orleans well under one-third the sediment it transported in historical times. The change is visible to the naked eye: waters that were once an opaque rusty brown are now a translucent, cloudy gray. The 890 milligrams of particles measured in 1846 now typically weigh in around 125 milligrams per liter, which, if one were to repeat Ingraham's drinking-glass experiment, would deposit a film immeasurably thin to the naked eye.

Anthropogenic alterations of the Mississippi River system have made river sediment a bit like fire: beneficial in some circumstances, a nuisance or menace in others. It is beneficial when it stays in place in Midwestern farms and Appalachian hillsides, producing crops, grasses, and trees. Once river-borne, it is—or rather, was—beneficial when, centuries ago, it replenished the Louisiana deltaic plain with new deposits of alluvium. To navigation, it has always been a nuisance, requiring costly dredging to keep particles mobilized and shipping routes obstacle-free. Once dams were installed, even mobilized particles became a hindrance, silting up reservoirs and necessitating costly maintenance, a problem that also afflicts flood-control structures and other infrastructure in the river. But no New Orleanians complained in the early 1800s when the river formed a batture adjacent to the Faubourg St. Mary, by fortuitously depositing sediment precisely at the right time and place where new land could be thoroughly utilized for urban and port development. (The entire Warehouse District and riverside portions of the French Quarter, CBD, and Lower Garden District now occupy this

[104] Generalized from data presented in Sherwood M. Gagliano and Johannes L. van Beek, "Mississippi River Sediment as a Resource," in *Modern Missisippi Delta—Depositional Environments and Processes*, ed. Ram S. Saxena (New Orleans, 1976), 109.
[105] Robert H. Meade, *Contaminants in the Mississippi River, 1987-1992* U.S. Geological Survey Circular 1333 (Denver, CO, 1995) 18.
[106] Ingraham, *South-West by a Yankee*, 1:60.

[107] De B.R. Keim, "The Mississippi River and Its Peculiarities," *Continental Monthly: Devoted to Literature and National Policy* 5 (June 1864): 635. This source, published in 1864, tabulated seventy measurements of sediment taken at New Orleans from May through August 1846, which averaged 6.5 "grains" per pint. One grain equals 64.8 milligrams.

feature.) Even fewer complained about the effects of river-borne sediment on agriculture: most of the sugar production that enriched New Orleans in the nineteenth century arose from alluvial deposits, as did much of the cotton. On the other hand, sediment discharged into the Gulf of Mexico in the late nineteenth century impeded shipping activity into the Mississippi, costing New Orleans critical economic activity as it struggled to recover from the Civil War. Capt. James Eads solved this problem in 1879 by building jetties to speed up the flow and clear out sediment building up at the mouth, but this infrastructure too requires maintenance and dredging, to this day. Sediment in the Mississippi River also influences the delivery of pollutants and trace metals, which bind to particles and may end up in New Orleans' water supply, as well as those of seventy or so other cities and towns.[108] The challenge presented by this sometimes valued, sometimes disdained natural resource to residents of the Mississippi basin is, how do we keep sediment from eroding from the land and accumulating in the Mississippi, to which the answer is soil conservation. The sediment challenge to those in the Mississippi delta is, how do we extract sediment from the Mississippi and put it to use on the land? The answer to this problem segues to the Mississippi River's role as creator of land.

River as Creator — No riverine influence is as fundamental to a city as the creation of its underlying terrain. This role is described in detail, from geological, pedological, and topographical angles, in preceding chapters. To recapitulate, the Mississippi River formed New Orleans' terrain, and that of southeastern Louisiana, as it emerged from its alluvial valley, slowed its velocity, and deposited its sediment load at the brink of the Gulf of Mexico. As it built this deltaic plain, its banks rose and occasionally developed crevasses, through which water rushed toward a new route to the gulf. If this route proved steeper and closer to the sea, it would eventually grab nearly all flow and form a new channel. In other cases, enough sediment accumulated at the mouth to block the river's final passage to the gulf, nudging it into a new, adjacent delta. This process repeated for seven millennia, with each channel building up more alluvium in new areas until the young deltaic plain rose above the level of the sea. Seasonal overbank floods of the Mississippi and its distributaries continued to coat the surroundings with new layers of sediment. These soils, high in water content and organic matter, naturally subsided into the sea, while the sea itself eroded their peripheries through wave action and occasional storms. Under natural conditions, however, the Mississippi deposited alluvium at roughly the rate at which the sea withdrew it.

Enter man, and circumstances changed. Louisiana society understandably could not tolerate river floods, and proceeded with the available engineering technology of the day to prevent the springtime deluges. Man-made levees arose along the New Orleans riverfront as early as 1719, and lined the river from English Turn to present-day Reserve by 1735, to the Old River region by 1812, and beyond Greenville, Mississippi, by 1844.[109] Though crevasses remained a dangerous threat to the human population, the river's seasonal overbank flooding was significantly reduced by the mid-nineteenth century and all but eliminated in the lower river by the mid-twentieth century, when the levee system, dramatically reinforced after the 1927 flood, spanned 1,600 miles along the lower river.

As the levees constrained the river, Louisianians increasingly began to notice disturbing trends throughout the coastal region. Coastlines and shorelines receded visibly within a few years. Small inlets interspersed with marshes expanded into sizable bays. Salt water intruded farther inland each year, turning freshwater swamps into saline marshes, then eroding the saline marshes. Cypress trees were dying. Land everywhere was subsiding, particularly in New Orleans. Percy Viosca, Jr., director of Fisheries for the state's Department of Conservation, sounded an early warning in his 1927 paper, "Flood Control in the Mississippi Valley in Its Relation to Louisiana Fisheries," which made the connection between levee construction and ecological decline.[110] Other scientists later confirmed the trends: sediment "withdrawals" were exceeding the "deposits," and coastal Louisiana was eroding into the Gulf of Mexico. Factors such as canal networks excavated for oil and gas exploration, navigation, fishing, and trapping increased erosion at the land/water interfaces and further exacerbated the situation. Additionally, marsh grasses died back during droughts or were devoured by invasive nutria; petroleum extraction created collapsible voids in the earth's volume; and sea level rose at increasing rates.[111] As a result, coastal Louisiana lost 1,200,000 acres of wetlands (1,875 square miles, nearly the size of Delaware) during the twentieth century, and continues to lose land at a rate of twenty-five to thirty-five square miles per year, or forty-five to sixty acres per day. Another 330,000 to 440,000 acres are expected to disappear between 2000 and 2050.[112] Headline newspaper stories about Louisiana's coastal erosion crisis appearing about six times per year in the 1990s more than tripled to a pace of twenty-one articles per year in the early 2000s.[113] What was once an obscure environmental concern known only to scientists is now the premier public concern of coastal-zone residents, for whom the situation is dire: departure of commercial and residential populations, threats to oil and gas infrastructure, damage to the $1 billion/year seafood

[108] Joann Mossa, "Sediment Dynamics in the Lowermost Mississippi River," *Engineering Geology* 45 (1996): 457-58.

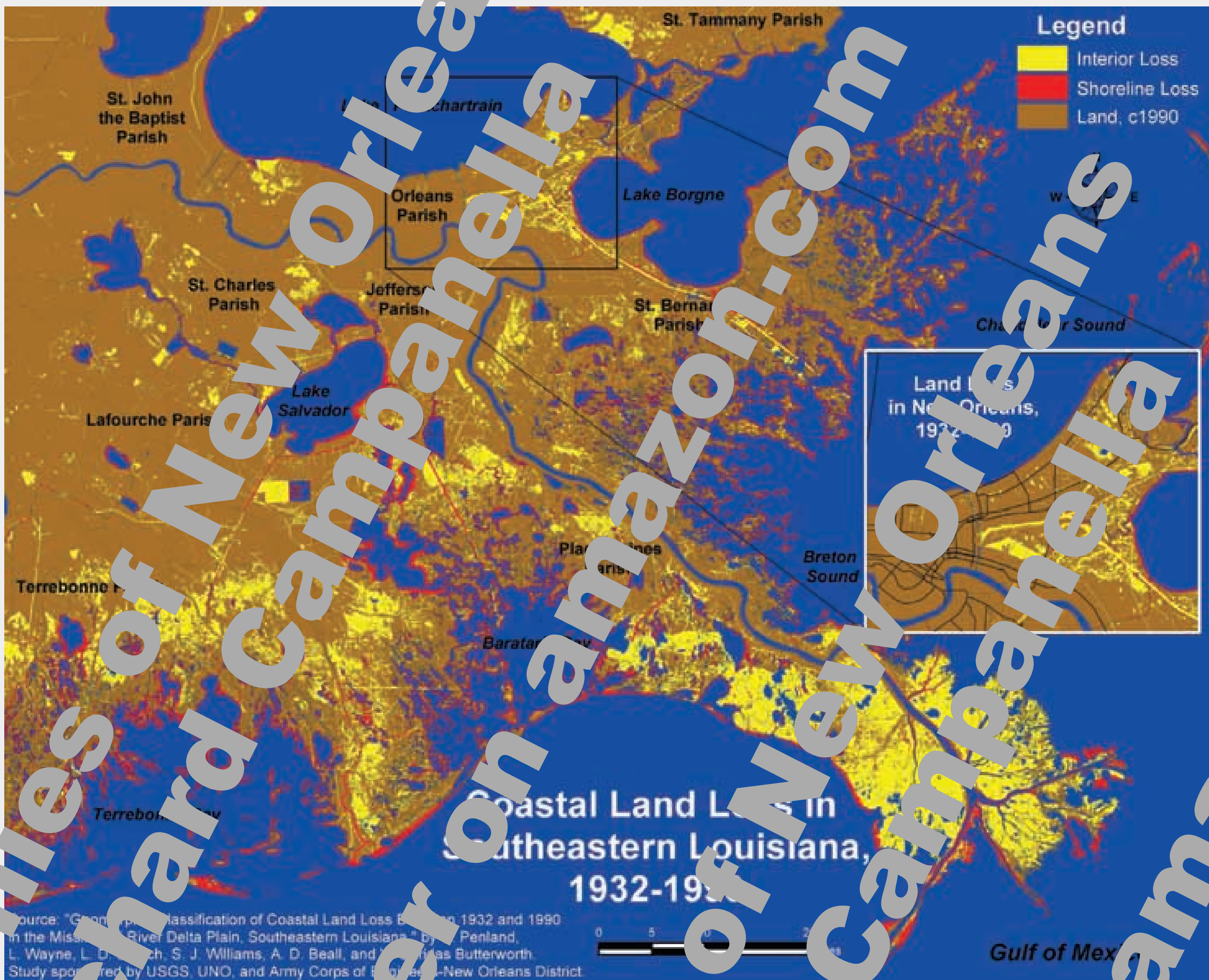
[109] Jesse H. Walker and Randall A. Detro, eds., *Cultural Diffusion and Landscapes: Selections by Fred B. Kniffen*, Geoscience & Man 27 (Baton Rouge, 1990), maps on p. 6-7.

[110] I thank Daniel Etheridge for bringing this paper to my attention.

[111] For further information on the causes of coastal erosion in Louisiana, see John W. Day, Jr., et al., "Pattern and Process of Land Loss in the Mississippi Delta: A Spatial and Temporal Analysis of Wetland Habitat Change," *Estuaries* 23 (August 2000): 425-38.

[112] "100+ Years of Land Change for Coastal Louisiana," U.S. Geological Survey National Wetlands Research Center and Louisiana Coastal Area Land Change Study Group, http://www.nwrc.usgs.gov/special/landloss.htm.

[113] Lexis-Nexis database search conducted on *Times-Picayune* articles with "coastal erosion" in the headline and "Louisiana" in the text, published between January 1993 and July 2004.

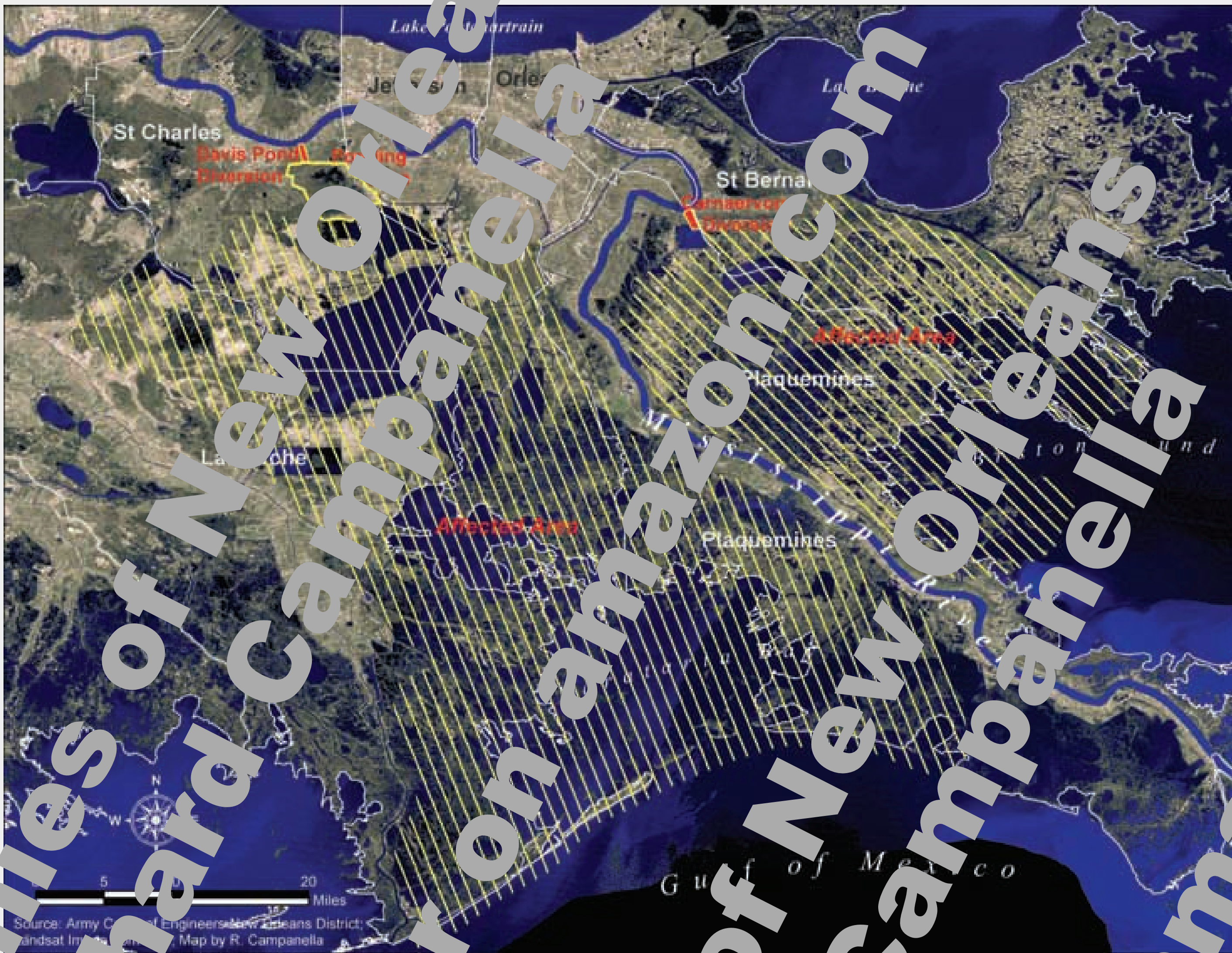


Levee construction on the Mississippi River, plus canal excavation, rising sea level, and other factors, have conspired to erode 1,875 square miles of Louisiana's coastal wetlands during the twentieth century. Another twenty-five to thirty-five square miles disappear annually. The diminishing buffer of coastal wetlands renders the city increasingly vulnerable to hurricanes: every 2.7 miles of wetland loss allows an extra foot of gulf water to surge inland ahead of a hurricane. New Orleans' future is in jeopardy if coastal erosion continues apace. *Map by author based on research by Penland et. al, USGS, UNO, and Army Corps.*

industry and the $220 million sport hunting business, diminishing wildlife habitat, a literal loss of real estate, and an end to a centuries-old way of life, particularly among Acadian and Creole peoples. Coastal erosion also threatens New Orleans: the parish lost at least 14,500 acres of land since 1932, mostly in the eastern marshes and much due to ill-advised canal excavation.[114] The eroding shores of lakes St. Catherine and Pontchartrain, and of connecting waterways such as Sawmill Pass, threaten the raised camps of the Rigolets—a New Orleans neighborhood, albeit a very unusual one—as well as Highway 90, an evacuation route from the city to rural Mississippi.[115] More significantly, the diminishing buffer of coastal wetlands renders the city that much more vulnerable to hurricanes. Every 2.7 miles of wetland loss allows an extra foot of gulf water to surge inland ahead of a storm, and in a bowl-shaped city half below sea level, storm surges present a far greater danger than wind and rain. In effect, the levee system transferred the source of the flood threat to southeastern Louisiana from the Mississippi River to the Gulf of Mexico.

The freshwater and sediment needed to reverse this gradual catastrophe remain trapped in the levee-constrained Mississippi River, emptying out uselessly into the Gulf of Mexico. Returning the river to its role of land creator requires addressing the question posed earlier: how do we extract sediment from the Mississippi River and put it to use on the land in a financially conservative program? The simplest and most radical solution is to simply "let it go:" cease maintenance of the levees, allow crevasses to develop, open up Old River and let the Atchafalaya and Mississippi fight it out naturally, and let the system heal itself. Most human residents would find the resultant floods and brackish drinking water to be utterly intolerable, and the impact on the local economy and society

[114] Computed from analysis by S. Penland, et al., *Geographic Classification of Coastal Land Loss Between 1932 and 1990 in the Mississippi River Delta Plain, Southeastern Louisiana* (New Orleans, 1932-1990).
[115] Mark Schleifstein, "Projects Make Initial Cut for Breaux Act Financing," *Times-Picayune*, February 4, 2005, A3.



The most practical large-scale solution to coastal erosion is the diversion of Mississippi River waters into the wetlands through control structures or crevasses in the levees. The freshwater pushes back the encroaching saltwater wedge and coats the subsiding wetlands with new sediments. The impact areas of the first two major river diversions, Caernarvon and Davis Pond, are shown on this map. Others diversions, crevasses, and siphons are planned for the near future. *Map by author based on Army Corps information.*

disastrous. So the question must be amended with two pragmatic conditions: in a cost-effective manner that minimally impairs human activity. The optimal solution appears to be river diversion—that is, the controlled re-creation of crevasses and overbank flooding by means of specially engineered breaks in the levee at carefully selected locations. River water has been intentionally diverted or siphoned at least since the 1830s to stimulate oyster, fish, and muskrat productivity, and at least since the 1750s for irrigation and mill power. Diversions were even made for land-building in antebellum times: A. Oakey Hall in 1846 or 1847 was "shown some six hundred acres of land on a plantation below New Orleans that some ten or twelve years ago was "manufactured" out of worthless swamp land by a season's irrigation [diversion] of the Mississippi River.[116] Modern controlled diversions built primarily for coastal restoration, with their attendant engineering and bureaucratic complexities, did not come to fruition until 1988-91, when the Caernarvon Freshwater Diversion Structure opened fifteen miles downriver from New Orleans. (Not coincidentally, Caernarvon was the site of the controversial dynamiting of the levee in April 1927, which sacrificed parts of St. Bernard and Plaquemines Parishes to secure New Orleans from the threat of record high water in the Mississippi that year.) Caernarvon was originally designed to enhance fish and shellfish productivity in the marshes of the Breton Sound Basin, by pushing the oyster-friendly five-to-fifteen-parts-per-thousand salinity zone farther outward toward the gulf. Only later did authorities and the public come to appreciate its more important role as a coastal restoration device. Caernarvon passes a maximum of 8,000 CFS into the marshes southeast of English Turn through a series of five culverts, a 1.5-mile outflow channel, a disposal area for dredged sediments, and an overflow basin. In its first dozen years of operation, "Caernarvon has increased over seven-fold the size of freshwater plant communities, reduced the area of saltwater vegetation by over 50 percent, rejuvenated fish

[116] A. Oakey Hall, *The Manhattaner in New Orleans; or Phases of "Crescent City" Life* (New York, 1851), 130.

The Caernarvon Freshwater Diversion Structure (center) diverts up to 8,000 CFS from the Mississippi into the marshes of Plaquemines and St. Bernard parishes (to the right). Opened in 1991, Caernarvon has pushed back saltwater intrusion, expanded freshwater vegetation communities, and created some new land. *Photograph by author, 2004; aircraft courtesy SouthWings, The Nature Conservancy, and [illegible]R.*

and wildlife populations, and stabilized the marshes"[117] of Plaquemines and St. Bernard parishes. In 2002, the Davis Pond Freshwater Diversion Structure opened near Luling, twenty-two miles above New Orleans, designed to release a maximum capacity of 10,650 CFS into 777,000 acres of Barataria Basin marshland. It is the largest coastal restoration project of its type in the world, and together with Caernarvon and other currently on-line structures, can divert up to 6 percent of Mississippi River flow when operating at full capacity. Where gated diversions are not practical, pipelines are used to siphon high river water over the levee to specific locations in the low-lying backswamp. Less costly to install but difficult to maintain suction, siphons are proposed to rebuild wetlands in eastern Orleans Parish, the only planned marsh creation that falls within New Orleans' limits. Where circumstances allow for a more natural approach, an old-fashioned crevasse is opened in the levee, sans gates or pipelines, allowing the water to spill through unimpeded. One such manmade crevasse is the West Bay Project, a twenty-five-foot deep cut in the levee about five miles downriver from Venice, through which up to 20,000-50,000 CFS of river water will pass. Currently under construction, West Bay promises significant land-building because of its large and unimpeded flow, and because it taps into a larger quantity of high-quality suspended sediments, not just the surface-level particles that controlled diversions use.[118] Many more openings, part of the Delta-Wide Crevasses Project, are planned for lower Plaquemines Parish, near the mouth of the Mississippi. In all, as of August 2003, the Army Corps of Engineers, the state of Louisiana, and other federal agencies oversee twenty-five gated diversions, siphons, crevasses, and auxiliary projects in planning, construction, or operational phases throughout southeastern Louisiana.

Perhaps the most ambitious proposed diversion is known as the Third Delta Conveyance Channel, conceived by geologist Sherwood Gagliano. This idea essentially seeks to re-establish Bayou Lafourche, a natural distributary of the Mississippi until it was mostly sealed off in 1904, as an active fork of the river. Because literally re-opening the levee would threaten the cities and agricultural communities of Bayou Lafourche, Gagliano proposes to create a conveyance channel east of the natural levee to carry sediment-laden river water into the marshlands. While the initial capacity would be 20,000 CFS, its eventual maturing would augment flow to 150,000 CFS—indeed a "third delta," equal to the Atchafalaya, and nearly a third the size of the Mississippi. A project of this magnitude may take decades to realize; diversions of any size are expensive and politically charged, and they are not without short-term detrimental side affects to the shellfish and fisheries industries, navigation, and the control of floods and pollution. Some geologists even question diversions' ability to build land, arguing that not enough of the right sediments (sand, rather than silt or clay) flow to the right place in

[117] U.S. Army Corps of Engineers, New Orleans District, *WaterMarks: Louisiana Coastal Wetlands Planning, Protection and Restoration News* 23, August 2003, 6.

[118] Sandra Barbier and Mark Schleifstein, "New Marsh Project Largest Diversion Yet," *Times-Picayune*, October 21, 2003, p. 1.

Seen here is Davis Pond's intake in the Mississippi River (left) and outflow canal into the backswamp near Luling, twenty-two miles above New Orleans. The diversion, opened in 2002, releases up to 10,650 CFS of river water into 777,000 acres of Barataria Basin marshes. It is often called the largest coastal restoration project in the world. *Photographs by author, 2004.*

the river (along the bank near the surface, where intakes are located) to accomplish that objective. It has been estimated that only 15 percent of the river's sediment load is available for land-building, the rest being trapped by upriver dams or directed to the gulf by navigation channels. "Mining" sand from the riverbed and pumping it to where it is needed may prove to be more effective, provided it can be done inexpensively at enormous volumes. But most scientists and managers agree that well-engineered river diversions—big ones, and lots of them—represent the last, best, and most realistic hope to save coastal Louisiana and New Orleans. After a century-long absence, the Mississippi River's role as creator of land has begun to resume.[119]

River as Threat — The Mississippi River threatens New Orleans with hazards even as it blesses it with resources. Chief among the river's threats to the eighteenth- and nineteenth-century city was its uncontrollability, manifested occasionally through bank erosion, potentially through channel jumps, and seasonally through the threat of spring flooding. Hernando De Soto's expedition bore first European witness to this annual phenomenon when the river flooded both sides of the channel for about fifty miles in March and April 1543.[120] Under natural conditions, the Mississippi River inundates its deltaic plain in two manners. Annual springtime high waters sometimes surpass the crest of the natural levee and spread over it a thin sheet of water (overbank flooding) flowing slowly down the land and toward the backswamp. Alternately, river water surges through a specific break in the natural levee (crevasse flooding), filling up the backswamp via a focused and sometimes torrential flow rather than a thin, slow-moving sheet. Overbank flooding inundates the deltaic plain from the riverfront, while crevasse flooding does so from the backswamp. Sometimes both types of flooding occur simultaneously, since waters that are high enough to spill over the bank may also be strong enough to penetrate a weak spot in the levee. Additionally, many local flood events are entirely attributable to Lake Pontchartrain, whose waters may be pushed upon adjacent marshes by storm surges from the Gulf of Mexico. One of the reasons the future New Orleans site appealed to Bienville during his explorations in 1699 and 1700 was that the riverfront land stood above the waterlogged backswamp at the time, which may have been flooded either by a distant river crevasse or by the lake. Those seasons turned out to be low-water years on the river; had Bienville first seen the area under overbank-flooding conditions, he may well have relented to pressures to locate New Orleans at Bayou Manchac or elsewhere.[121] During the clearing of forest in the spring of 1718, the Mississippi River threatened the nascent outpost with overbank flooding, interrupting the men's work and forcing them to erect a makeshift dyke to keep river water from breaching the crest of the natural levee. Water higher than even the natives had ever seen arrived in April 1719, smothering the settlement with a half-foot of water and forcing the men to transform the temporary earthwork into a permanent levee, commencing the era of levee construction on the Mississippi River. A complete chronology and characterization of New Orleans floods in the century that followed resists easy compilation, because no single standard was applied to judge exactly what constituted a flood event, and no agency in historical times kept consistent records of location, duration, severity, or cause. According to one circa-1882 public health 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"[122] occurred in [illegible], 1837, 1846, possibly in 1853 and 1854-1855, 1856, 1861, 1868, 18[illegible], 1871, and 1881. Data on lake-direction floods prior to [illegible] were either lost or never recorded, but the source notes that such floods were "much more numerous" than direct overbank flooding from the river, which became increasingly rare with improved levees.[123] Gould's *Fifty Years on the Mississippi* adds 1780 to the list of colonial-era crevasse floods; Kendall's *History of New Orleans* ([illegible]) adds 1813 to the record of crevasse floods and 1844 as a lake flood; and a recent Army Corps of Engineers source adds 1850, 1858, [illegible], 1867, and 1874 to the list of flood years.[124] In 1890, a river crevasse raised the level of the lake, which was pushed inland by winds, flooding the city up to the Metairie Ridge. Another study found that the river reached flood stage at New Orleans (but did not necessarily flood the city) at an interval of once every 4.07 years, from 18[illegible] to the 1930s.[125]

"*Crevass[es]*, the name given to a fissure or breaking of the Levée," wrote John Adems Paxton in 1823, "are occasioned by two causes: first, the yielding of the Levée; and secondly, the sinking of the bank of the river: the former kind could in some instances, be prevented by prudently retiring the Levée from the immediate margin of the river; the latter is more frequent, and is almost uniformly produced by neglect."[126] Their unpredictability and difficulty to repair made crevasse floods accountable for the city's worst deluges—and made the French term *crevasse* ("crack") a dreaded word in the nineteenth-century Louisiana lexicon. On May 6, 1816,

[119] U.S. Army Corps of Engineers, New Orleans District publications: *Louisiana Coastal Area* (2003); *Freshwater Diversion* (2003); and *WaterMarks* (2003).

[120] Richard Joel Russell, "Physiography of Lower Mississippi River Delta," *Lower Mississippi River Delta: Reports on the Geology of Plaquemines and St. Bernard Parishes*, Geological Bulletin 8 (New Orleans, 1936), [illegible].

[121] E.W. Gould, *Fifty Years on the Mississippi; Or, Gould's History of River Navigation* (St. Louis, MO, 1889), 223.

[122] "This lake aided by the river" describes what occurred in 1871, when a crevasse at Bonnet Carre introduced river water to the lake, which in turn rose and inundated New Orleans with waters that were generally clear of sediments.

[123] Stanford E. Chaillé, "Intimations of New Orleans and Their Influence on Its Health," *New Orleans Medical and Surgical Journal* (July 1882), excerpt in Tulane University Special Collections Vertical File, Flooding folder, 3.

[124] Gould, *Fifty Years on the Mississippi*, 225; Kendall, *History of New Orleans*, 1:167-69; Army Corps of Engineers, New Orleans District. *Bonnet Carré Spillway*. Agency booklet, circa 2000.

[125] As cited by Russell, "Physiography of Lower Mississippi River Delta," 19.

[126] John Adams Paxton, *The New-Orleans Directory and Register* (New Orleans, 1823), 138.

a weak spot in the levee on Barthélemy Macarty's plantation in present-day Carrollton opened into a crevasse, letting river water fill up the backswamp and ascend the backslope of the natural levees to the very heart of the city. "One could have in a skiff from the corner of Chartres and Canal streets to Dauphin, down Dauphin to Bienville, down Bienville to Burgundy, thus to St. Louis Street, from St. Louis to Rampart, and so throughout the rear suburbs."[127] But even with this destructive river-caused 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."[128] (This deposition helped form the high ground along South Carrollton Avenue.) That summer also proved to be unusually healthy for the population—there were only 6[illegible] deaths in New Orleans in 1816, compared to 1,252 in 1815 and 1,772 in 1817—possibly due to the massive unplanned spring cleaning of the filthy port city.[129] Thirty-three years later and one riverbend above the Macarty crevasse, the levee broke on Pierre Sauvé's plantation in present-day western Metairie, between Harahan and Kenner. Starting May 3, 1849, river water poured through a crevasse that would later grow to 150 feet long and six feet deep, accumulating in the backswamp between the natural levee of the Mississippi and the Metairie Ridge. It surpassed the New Basin Canal and its upraised Shell Road on May 8, reached Rampart Street on May 15, and peaked on May 30, flooding as far as Carondelet Street. Uptown, water covered parts of the upraised tracks of the New Orleans and Carrollton Railroad (present-day St. Charles Avenue Streetcar Line) by up to four inches.[130] A few weeks later, a *Daily Picayune* journalist climbed the cupola of the St. Charles Hotel and described the view from the 185-foot-high perch:

> Far away to the utmost extent of vision toward Carrollton, and above, leading to the lands in the vicinity of the Sauvé crevasse, the surface of the country on the left bank of the Mississippi is one sheet of water, dotted in innumerable spots with houses.barns, out houses, lofty trees and brushwood, in all their interminable variety…. The whole of the streets in the Second Municipality…are now so many vast water courses, or aquatic highways, issuing as it were from the bosom of the swamp…. Indeed, there is no place with which we can compare New Orleans…, that would give the absent traveller so correct an idea of its topographical features, as the city of Venice.[131]

The crevasse was finally plugged on June 20, but not before 220 city blocks with 2,000 structures and 12,000 residents were flooded by a single leak in the levee almost seventeen miles away. Pavement, gutters, wharves, levees, and city structures were so damaged that a special tax had to be levied the next year to pay the bills.[132] It was the worst crevasse flood ever to affect New Orleans, though by no means the last: a crevasse developed near the Garden District in 1862 and four reoccurred at Bonnet Carré between 1849 and 1882.[133] Beneath layers of concrete and artificial fill in the area between Sauvé Road in Jefferson Parish and the rear of the French Quarter lies a thin layer of 1849 river sediment, one of the last major flood-borne deposits made upon the cityscape created by then.

"May Heaven avert from us such another catastrophe! May our citizens, in their foresight and their intelligence, devise some means of raising an insuperable barrier to another inundation from [the Mississippi River]!"[134] So implored the *Daily Picayune* journalist on June 4, 1849, concluding his report on the historic magnitude of the Sauvé flood. His prayer was answered within a few decades: increasingly sophisticated and extensive levee construction following the establishment of the Mississippi River Commission and the federalization of flood control (1879) greatly reduced the threat of Mississippi River flooding to New Orleans. The increasing height and length of levees reduced the risk of overbank flooding in the region, while the increased quantity of levees diminished the chance of crevasse flooding. When the Great Mississippi River Flood of 1927 inundated most of the lower Mississippi Valley, from Cairo to the delta of the Atchafalaya River, New Orleans was saved by its levees from what would have been a catastrophic deluge. That a crevasse was dynamited in the Caernarvon levee below New Orleans, to ensure further the safety of the prosperous city at the expense of poor, rural St. Bernard and Plaquemines parishes, remains one of the most controversial and bitter incidents in local history. The 1927 flood revealed the imprudence of the long-standing "levees only" policy for Mississippi River flood control, and demonstrated the need for measures that accommodate the will of the river, in addition to the levees that constrain it. After the disaster, spillways at Bonnet Carré and Morganza—which are essentially controlled crevasses—were installed to complement the manmade levees that had been the only line of defense against the threat of the Mississippi from 1719 to 1927.

That the word "crevasse" is rarely heard today beyond historical and geological circles is an indication of the success of the Army Corps of Engineers' flood control policies. The Mississippi River still potentially threatens New Orleans—the Bonnet Carré Spillway has been used in 1937, 1945, 1950, 1973, 1975, 1979, 1983, and 1997—but not in over a century has Mississippi River water significantly impinged directly upon Orleans Parish. Yet the legacy of the old threat lingers in the city's memory. River flooding caused massive property damage and public-health problems from the early 1700s to the late 1800s, forcing private citizens and governments at all levels to invest immeasurable resources

[127] Waring, *Report on the Social Statistics of Cities*, 261.
[128] Wilton P. Ledet, "The History of the City of Carrollton," *The Louisiana Historical Quarterly* 21 (January 1938): 228.
[129] Chaillé, "Inundations of New Orleans and their Influence on Its Health," 5.
[130] Kathryn C. Briede, "A History of the City of Lafayette," *The Louisiana Historical Quarterly* 20 (October 1937): 951.
[131] "The Inundation," *Daily Picayune*, June 4, 1849, Monday evening edition, p. 2, col. 1.
[132] Waring, *Report on the Social Statistics of Cities*, 261-62.
[133] See "The City" columns in *Daily Picayune* of May-June 1862 for accounts of this little-known potential disaster, which occurred as the city surrendered to Union forces during the Civil War.
[134] "The Inundation," p. 2, col. 1.

into flood-control projects. This diversion of civic resources surely has come at the expense of the economic well-being of the city. The flood threat is also manifest in the city's historical geography, vis-à-vis its physical expansion, its architectural adaptation, its real estate values, even its racial patterns: poorer blacks lived closer to the flood-prone riverfront and backswamp, while wealthier whites lived in the safer areas between. Today, manmade levees and floodwalls form the single most significant landscape feature in the region, rising high above all surrounding deltaic terrain, orienting residents to the local layout of the land, and securing them against what was once a dreaded annual threat. Worried eyes now look to Lake Pontchartrain and the adjoining Gulf of Mexico as the premier flood threat to the city, whose waters would rise with the force of a perfectly situated hurricane and pour into the New Orleans topographic bowl.

With the flood hazard in check, a remaining threat posed by the Mississippi River is its role as a pathway of pollutants gathered from the 1,243,700 square-mile watershed and ushered past New Orleans. A pollutant, or contaminant, is any foreign (or over-abundant) substance that registers deleterious affects upon the ecology, economics, or human health of the river-influenced region, including its estuary. As the major city nearest the mouth of the river, New Orleans bears the effects of much of what is dumped, dug, eroded, spilled, sprayed, flushed, treated, manufactured, and paved throughout its hinterland. "Living downstream" is a fate of all port cities, but the burden upon New Orleans is multiplied by the sheer size of its hinterland, its dependency on the Mississippi, and its position 96 percent of the way down the river. Whatever the source of the problem—from huge Midwestern agribusinesses to morning cups of coffee—if it ends up in the Mississippi, it will eventually be New Orleans' problem.

Pollutants may be grouped into two overlapping categories: those that can cause health problems and those that disrupt ecosystem functions. Among those affecting the health of humans and other species are organic chemicals such as pesticides and petroleum products; inorganic chemicals including metals and acids; infectious agents such as bacteria and viruses; and radioactive materials like uranium. Pollutants potentially altering ecosystem functions include nutrients such as nitrates, ammonium, and phosphates; sediment; biota nonnative to the ecosystem; waste and debris; salinity; and temperature changes.[135] Regardless of affect, pollutants are released into the Mississippi watershed in two ways. Those released from point sources, such as sewers, outfalls, mines, and wastewater effluents, generally flow directly into water bodies (treated or otherwise) and toward the Mississippi and New Orleans. Others, in much greater quantities, disperse from non-point sources, such as farms where pesticides and herbicides are sprayed, cities and towns where polluted rainwater runs off, or fields and forests where acid rain falls, and take the slow road toward their fate. A pesticide sprayed on a cropland, for example, may (1) run off the surface and into streams and rivers; (2) evaporize and return with rainfall; (3) absorb into vegetation for consumption by animals or humans; (4) leach into the soil and enter the aquifer; or (5) chemically break down into other compounds. Depending on a multitude of factors, most molecules will degrade over time, but at least some will eventually find their way into the Mississippi. Once riverborne, pollutants travel by binding to sediment particles either suspended or dissolved in the water column or in the bedload. For thousands of river miles from its entry into the system to the banks of the New Orleans metropolitan area, a pollutant molecule is at the mercy of the larger sediment flux, chemistry, and flow dynamics of the Mississippi River.

New Orleans' potable water quality was notoriously bad until the early twentieth century. So foul was the piped water in 1854 that a German newspaper urged its readers to "drink no water—drink beer!"[136] Most people avoided the problem altogether by resorting to cistern-collected rainwater, until the municipal system was finally opened in 1908 and the Mississippi River became the exclusive source of the city's potable water. Judging from city newspapers, New Orleans awoke slowly to the threat of Mississippi River water pollution: articles about water pollution numbered four in the 1930s, seven in the 1940s, eight in the 1950s, then exploded in the early 1960s, when river and lake pollution hit the front pages consistently. One hundred fifty-two articles about local water pollution appeared in city papers in 1960 to 1963 alone, including reports on "a sea of black crude oil... floating down the Mississippi River toward New Orleans;" "a nauseating experience to drink this water" after Esso Standard Oil spilled phenol in the river in Baton Rouge, and the on-again, off-again closures of Pontchartrain Beach due to lake pollution.[137] Much of the river pollution in the early 1960s came from chemical and oil spills from river vessels, exacerbated by particularly cold winters (which diminished biological breakdown of the compounds) and low river stages (which minimized dilution).[138] News reports, editorials, and political cartoons both reflected and produced increasing public concern about the threat of water pollution. Over the next decade, similar sentiments nationwide led to the formation of environmental protection agencies at the federal and state levels, passage of the Clean Water Act, and countless other legislation and regulations aimed at reducing water and soil pollution. So great was the change in public opinion and legislation in the latter twentieth century that one tome divided

135 William P. Cunningham and Barbara Woodworth Saigo, *Environmental Science: A Global Concern* (Boston, MA, 2001), 449-55.

136 *Die Tägliche Deutsche Zeitung*, September 23, 1854, p. 2, col. 5.

137 "Mass of Oil in River Pours Toward City," *Times-Picayune*, February 2, 1960, 1; "Water Mains to Be Flushed Today as Improvement in Taste Grows," *Times-Picayune*, January 15, [illegible]. Number of pollution articles was tabulated through the "Water Pollution" category of the New Orleans newspaper catalog (which covers articles from 1804-1963), housed in the Louisiana Room of the Main Branch of the New Orleans Public Library.

138 "River Pollution Laid to Vessels," *New Orleans States-Item*, February 18, 1963, p. 1.

The history of water quality management [illegible] two eras: from ancient times to Earth Day 1970, and from that symbolic day afterward.[139] Whatever one's judgement of Mississippi River water quality at New Orleans today—municipal authorities assert its safety even as environmentalists sound alarms—all would agree that it is far better than it was a generation ago. According to the Natural Resources Defense Council, these selected "key contaminants" remain cause for concern in New Orleans' tap of Mississippi River waters:[140]

• Atrazine, an organic pollutant used as a weedkiller, was detected locally at the national standard in 1999, but has since declined. Sprayed on croplands (including local sugarcane) at levels of 35,000 tons per year, atrazine can damage organs and possibly cause cancer. Recent research indicates that this herbicide, produced entirely in nearby St. Gabriel and used internationally as one of the world's most popular agricultural applications, may also disrupt species' endocrine systems, resulting in the mis-transmission of hormonal signals and possibly sex reversal and other reproductive problems.[141]

• Fecal coliform bacteria have been found locally in small quantities in 1999-2001. While this microbial contaminant itself is not a concern at the levels detected, its presence "may indicate some regrowth of bacteria in the water mains after the water leaves the treatment plant, [which] may allow disease-causing pathogens to subsist in pipes."

• Turbidity (cloudiness) levels, another potential indicator of pathogens, nearly reached the EPA limit in 2000-2001. Turbid water may be contaminated with the waterborne microbial disease *Cryptosporidium*, which can pose a threat to people with weakened immune systems and was detected in small amounts in local tap water in 1998.

• Arsenic, an inorganic pollutant associated with industry, mining, and now-banned pesticides, as well as natural geological processes, has been detected at average levels of under one part per billion, below EPA standards but still possibly posing a cancer risk.

• Lead, a heavy metal with serious adverse affects on the health and development of young children, leaches into tap water through pipe or faucet corrosion. Levels of lead in the Mississippi River at New Orleans are lower than those of most major cities and because the "hardness" of local waters

[139] Vladimir Novotny, *Water Quality: Diffuse Pollution and Watershed Management* (New York, NY, 2003), 1-10.
[140] Natural Resources Defense Council, 156-62; see also Meade, *Contaminants in the Mississippi River, 1987-1992*.
[141] John McQuaid, "Something in the Water," *Times-Picayune*, January 26, 2003, p. 1.
[142] Natural Resources Defense Council, 157.

fortuitously tends to prevent pipe corrosion, New Orleans is generally in good shape in this regard. Lead-based paint on old houses, however, is a major health concern, as it is on old bridges: when the Algiers-bound Crescent City Connection was repainted in 2002, paint chips falling into the Mississippi caused a spike in tests for lead at points downstream.[143]

Hundreds of other pollutants flow in the Mississippi River past New Orleans at levels usually low enough to pose minimal threat to humans—but not necessarily to other living things or to the ecosystem. Consider the excessive nutrients in the river, derived mostly from nitrogen and phosphorous used on Midwestern farms, as well as urban runoff, sewage, and animal waste. While this massive application of fertilizer helps make the Mississippi River basin the world's most productive agricultural region, the nutrients eventually flow out to the Gulf of Mexico, where they stimulate algae growth in the freshwater layer sitting atop the heavier salt waters of the gulf. The algae then bloom, die, sink to the bottom, decompose, and, unless the water is regularly mixed, deplete oxygen. When oxygen falls below two parts per million, most marine life is driven away or killed, creating a hypoxic ("low oxygen") zone in what was once a rich fisheries resource directly benefiting Louisiana's billion-dollar fishing industry. In a typical summer, this so-called "dead zone" spans 5,000 square miles along the inner- and mid-continental shelf, from the Mississippi birdfoot delta westward to the Texas coast.[144] Sometimes hypoxia reaches into Lake Pontchartrain by means of the Mississippi River-Gulf Outlet (MR-GO), a navigation canal excavated between 1958 and 1968, which has since caused myriad environmental problems.

Consider also a more unconventional form of pollution: the incursion of species not native to the region by means of the Mississippi River. In the 1990s, four species of Asian carp used to control vegetation in Arkansas and Mississippi fish farms escaped and made their way into the Mississippi River system. At first they spread north, causing concern upstream for their competition with native commercial fisheries and for their hazardous tendency to leap out of the water toward surface disturbances—such as unsuspecting boaters. They also spread south: in spring 2003, a local fisherman netted fifteen specimens of bighead Asian Carp, a native of China, in the Mississippi River by Kenner.[145] Soon, the invasive carp were found as far downriver as the Mississippi and Atchafalaya deltas. It remains to be seen what ecological and economic impact this newcomer poses to the New Orleans area, but it is hoped that it will be less than another riverborne invasive species: zebra mussels. This Caspian Sea mollusk first arrived in North America in 1988 by means of ballast water discharged by oceangoing vessels upon arriving in the Great Lakes region. Spread further by attaching to barges and other vessels, zebra mussels entered the Mississippi River system and diffused rapidly to southern Louisiana, causing millions of dollars of damage by encrusting utility intakes and other industrial and municipal infrastructure along the river.[146] While the Mississippi as a waterway has served to diffuse Asian carp and zebra mussels, the river as a shipping route has enabled the introduction of hundreds of other exotic species, both intentionally and accidentally. Among the more infamous accidental introductions was the Formosan termite, by means of wooden shipping palettes brought in from East Asia during World War II. Formosan termites are the bane of New Orleans homeowners, a drain of $300 million in damage and control efforts annually in the city, and a serious threat to two of New Orleans' greatest treasures: its live oak trees and historic architecture. Another nonnative, *Aedes aegypti*, had a far deadlier affect: the Yellow Fever mosquito, probably introduced from Africa via slave ships arriving up the Mississippi River to colonial Louisiana, killed approximately 100,000 Louisianians between 1796 and 1905.

Invaders of a human sort have rendered the Mississippi River an Achilles heel to the New Orleans area since 1699, when Bienville denied the English frigate *Carolina Galley* its mission of colonizing French Louisiana. The incident ended peacefully and left behind only the toponym "English Turn" for the river's last great meander, but it taught future New Orleanians that the strategic geographical situation that blessed their city also attracted enemies and gave them convenient passage. The English would return in 1814 and 1815, treading the river's natural levee rather than sailing its waters, and again New Orleanians rebuffed the invaders, this time with much shedding of blood—English blood. Come the Civil War, the strategic position of New Orleans and the Mississippi made them key targets of the Union's "Anaconda Plan" to encircle and subdue the Confederacy. The city fell early in the war (May 1862), and when the last Confederate strongholds on the Mississippi surrendered at Vicksburg and Port Hudson in July 1863, the end was inevitable. The mouth of the Mississippi was guarded against German U-boat infiltration during World War II, and in 1942, the war came within forty-five miles of the mouth of the river, when a U-boat sunk the *Robert E. Lee* passenger freighter and later itself was destroyed. During the War on Terror in the early 2000s, authorities identified New Orleans as a "top 10" target for terrorist infiltration,[147] for both its target-rich environment and its river accessibility. The sophisticated security devices now being installed on shipping containers and port facilities are the modern-day equivalents of the nineteenth-century masonry forts standing vigil along the river and adjacent marshes: bastions against those who seek to exploit the riverine access to the American interior, by means of New Orleans. It is no coincidence that, prior to September 11, 2001,

143 Sarah M. Bloom, "River Contaminated with Lead, Bridge Work Halted; Investigation Ordered," *Times-Picayune*, June 9, 2002, p. 31.
144 U.S. Geological Survey, National Wetlands Research Center.
145 Aaron Kuriloff, "CARPetbaggers: The Appearance of Several Species of Asian Carp in Louisiana Has Scientists Worried," *Times-Picayune*, June 23, 2003, p. 1.
146 U.S. Geological Survey, "Nonindigenous Aquatic Species," http://nas.er.usgs.gov/.
147 Michael Perlstein, "As 'Top 10' Target, N.O. Mounts a Defense; Local Security Chief Provides an Update," *Times-Picayune*, September 11, 2003, A15.

the last major foreign attack on an American state occurred on the plains of Chalmette on January 8, 1815: the Battle of New Orleans.

Other Roles

Roles played by the Mississippi in politics, economics, engineering, and culture underscore much of the history and geography of New Orleans. Politically, the river drew initial interest in the region from colonial and later American powers, each seeking to control the sole access route to the North American interior. The river served as a delimiter in the political subdivision of the region among competing powers and, later as an American possession, as a boundary among states, counties and parishes, municipal districts, wards, and a litany of smaller political geography entities. No greater geo-political role has ever been played by the Mississippi River than the Louisiana Purchase in 1803. Even New Orleans' street network pays indirect homage to the river: the French arpent system, used to delineate plantations perpendicularly to the river, passed the contours of the Mississippi on to the geometry of longlot properties, to which the urbanization process conformed as New Orleans expanded upriver. Though unseen by 99 percent of the population 99 percent of the time, the river nevertheless exerts a formidable impact on local culture, as an orienting feature ("riverside," "upriver," "downriver") embedded in the local lexicon, as an allusion in countless songs and stories, and as a "geographic and psychological barrier"[148] separating the more prosperous and famous East Bank from the oft-spurned West Bank.

The Mississippi River's most important role to the city is its economic one, as a conduit through which pass 6,000 ocean-vessels per year, with 2,000 depositing or loading nearly 90 million tons of cargo at the Port of New Orleans. It is the fourth busiest port in the nation, but easily ranks first when combined with the nearby River Road-based Port of South Louisiana. The Port of New Orleans alone supports over 107,000 jobs, spends $13 billion per year, earns an additional $2 billion, and contributes $231 million to state tax coffers annually.[149] Relative importance of the river and port to New Orleans was even higher in the past: most, indeed close to all, of New Orleans' spectacular wealth and meteoric rise between Americanization in 1803 and the Civil War in 1861 can be traced to river-related activity, as a cotton and sugar port and later as a handler of coffee, tropical fruit, and bulk cargo. "So long as New Orleans enjoys her present advantages by location on the Mississippi river," wrote the *New Orleans Bee* in 1836, "so long will her commerce continue to be augmented, and her property ensured." The townhouses of the French Quarter, the mansions of the Garden District, and most other vestiges of an opulent past derive from this "superiority of nature advantages,"[150] and it is these historical attributes that the city's ten-million-plus visitors come to see. Perhaps in the future the Mississippi will serve as a conduit not just for cargo but data, as it offers a convenient distribution system for optical fibers and other circuitry of the information age.

Volumes may also be written on the cultural influences of the Mississippi River upon New Orleans. The river served as a cultural conduit, drawing immigrants, boatmen, and travelers into the Mississippi Valley and to New Orleans, and as a pipeline that injected a cosmopolitan, open-minded atmosphere into the port city. It also brought rural Americans, from Kentuckian riverboatmen in the early 1800s to emancipated slaves later in the century, downriver to the city, where many of their descendants remain. That around-the-clock, city-of-strangers characteristic, coupled with the sense of physical isolation, helped form the city's reputation for the raffish and the rowdy, another pillar in today's tourism industry. Bourbon Street is a direct descendant of this reputation.

At least for its first two centuries, the Mississippi River also diffused New Orleans culture upwardly, sending its merchants with their money and citizens with their worldview—and their language, music, and food—to points upriver. The nature and magnitude of this diffusion awaits serious scholarly investigation. The notion of jazz spreading "up the river from New Orleans," for example, is oversimplified: railroads, phonographs, the Tin Pan Alley music industry, and radio had far superseded the river's ability to diffuse musical culture over the course of the late nineteenth and early twentieth centuries. One sees some Crescent City characteristics in other cities of the lower Mississippi River, but on the whole, New Orleans is more noted for its distinction from its hinterland than for its contributions to it. Nevertheless, in antebellum times, New Orleans played an influential role in the culture and economy of the South by means of its riverine position. That the sobriquet *Dixie* probably originated from the local *dix* (ten) dollar bills, issued by a New Orleans bank and circulated throughout the river region, symbolizes the city's influence upon the valley in the early nineteenth century, and the role of the river as the cultural pathway.

A Geography of the Past?

Just as *Dixie* is disappearing from the American lexicon, New Orleans' influence upon the South and nation, too, is diminishing, in proportion to the declining importance of the Mississippi River in American life. People no longer travel the river in significant numbers, nor had they during the entire twentieth century. Railroads, interstates, and air links to major hubs (not to mention telecommunications) diffuse immeasurably more culture, in all its manifestations, than does the river. Likewise the Mississippi, as important as it remains to the national shipping system, has long since relinquished its monopoly on access to the Mississippi Basin. A century

[148] Michelle Krupa, "Aiming for the Green," *Times-Picayune*, April 27, 2005, A6.

[149] U.S. Army Corps of Engineers Water Resources Support Center; Port of New Orleans, Navigation Data Center, "Tonnage for Selected U.S. Ports in 2000," http://www.iwr.usace.army.mil/ndc/wcsc/portname)).htm.

[150] *New Orleans Bee*, June 10, 1836, p. 2, col. 2.

and a half ago, a Mississippi cotton grower or Louisiana sugar planter had little choice but to ship his harvest on the river through New Orleans to reach its buyers, thus enriching the city in the handling, marketing, and processing of the commodity. He probably also used the river to get to New Orleans to conduct business, meet with financiers, send his children to school, socialize and entertain, and buy supplies for his estate. Today, a cotton or sugar producer has numerous shipping and handling options to get his commodity to market, few of which involve either the Mississippi or the Crescent City, and might only need to come to New Orleans for a trade show or convention—*by air*. New Orleans' Mississippi monopoly began to falter as early as 1825, when the Erie Canal gave the Eastern Seaboard waterborne access to the western frontier. More canals followed. By the 1830s, "an increasing percentage of western produce traveled on the canals directly to the East. New Orleans' share of the total western output was decreasing, but the tremendously rapid rate of growth taking place in the agricultural West concealed New Orleans' declining position."[151] Getting a shrinking share of a dramatically growing pie, New Orleans lulled itself into complacency, over-depending on the Mississippi River and failing to develop back-up competitive advantages in industry and the latest transportation technologies, namely railroads. Competition from railroads, rising from zero in 1830 to 9,000 miles of railroad track in 1850 and 193,000 miles in 1900, further eroded the city's once-exalted destiny. Whereas water-borne transportation moved nearly all freight in early nineteenth-century America, only about 15 percent of intercity commercial freight moves on inland waterways today; the rest is handled by railroads, trucks, pipelines, and aircraft.[152] Many factors explain New Orleans' decline from the heady visions of the early nineteenth century, when pundits and pontificators predicted that the city would someday rank among the richest and most important on earth. Chief among them is the simple fact that its riverine *raison d'être*, despite its magnitude and magnificence, is much less critical to the nation than it once was. New Orleans today may be viewed as a grand and splendid vestige of an economic geography that no longer exists.

The bonds that link New Orleans to the Mississippi River are fewer and weaker than in the day when America depended heavily on waterborne transportation. Yet a survey of the great river from the levee at Jackson Square rarely fails to convey a sense of awe and reverence, like that held by an essayist in 1866:

> In the river itself—the majestic river—lies that full of power, which is the highest beauty, for it reaches the sublime. An earthly shadow of omnipotence and eternity, it rolls on as it did ages ago in the unknown past, and it will roll on in the same grandeur until time shall be no more.[153]

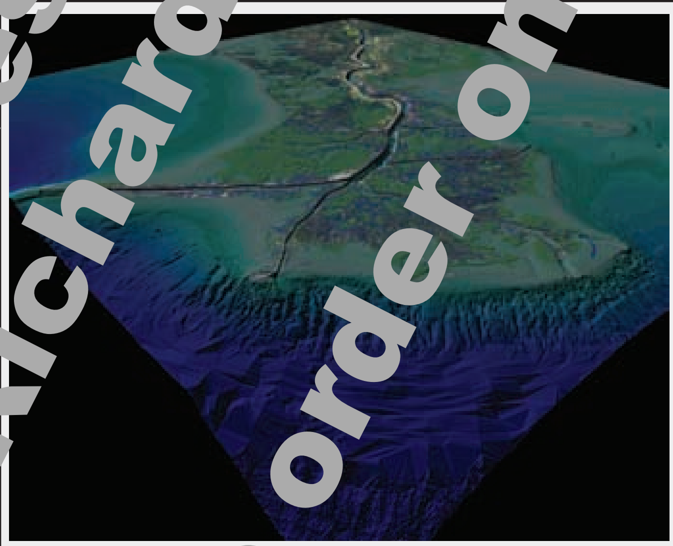
Epilogue: Katrina's assault on the coastal wetlands will force managers to reevaluate earlier plans for river diversions and siphoning. The new situation may render plausible radical strategies such as large-scale crevasses and levee openings, allowing for fast and cheap wetlands restoration and perhaps some protection from the next storm. But this would come at the cost of navigation needs and the human communities that have been part of the lower-river landscape since colonial times.

The Mississippi River played a background role during the drama of Hurricanes Katrina and Rita. The storm surge from the Gulf of Mexico arrived almost exclusively via lakes Pontchartrain and Borgne and manmade drainage and navigation canals, not the Mississippi. But the river did swell from its typically low late-summer stage of about four feet to nearly sixteen feet above normal sea level—practically flood stage—and spilled over laterally in parts of lower Plaquemines Parish. In New Orleans proper, the Mississippi came to be seen as a sort of riverine refuge: a destination for those wading out of the deluge to head toward to reach dry land, a place for rescuers to dock their vessels for a safe night's sleep, a source of desperately needed fresh water, and a possible route for future evacuations. After one hundred years of sprawling outwardly toward the lake and the drained marshes, New Orleans may now look back to the river, reconstituting the crescent-shaped city and giving its historical moniker renewed meaning.

[151] Merl E. Reed, "Boom or Bust: Louisiana's Economy During the 1830s," in *The Louisiana Purchase Bicentennial Series in Louisiana History*, vol. 16, *Agriculture and Economic Development in Louisiana*, ed. Thomas A. Becnel (Lafayette, LA, 1997), 13.

[152] Smithsonian National Museum of American History, *America on the Move* Exhibit, visited February 19, 2005. Freight data are from 2000.

[153] "The Mississippi," *New Orleans Times*, November 23, 1866, p. 3, col. 1.



This computer-generated perspective of the birdfoot delta of the Mississippi River, vertically exaggerated forty-fold for visibility purposes, was developed from multibeam SONAR-based water depth data combined with LIDAR-based terrestrial elevation data. The continental shelf appears in the foreground. *GIS processing by author based on data from C&C, Louisiana Department of Natural Resources, and University of Louisiana at Lafayette.*