Forming the Landscape

Mud, mud, mud . . .
this is a floating city,
floating below the surface of the water
on a bed of mud . . .

—Benjamin Henry Boneval Latrobe, 1819

Of Ice, Water, and Sediment

Geological origins of southeastern Louisiana and the New Orleans region

For millennia, the footprint of the earth's surface currently occupied by New Orleans and southern Louisiana altered between terrestrial and aquatic states. In times of cooling global temperatures, increasing quantities of the planet's water froze as glaciers, thus lowering sea level and dewatering coastal fringes. When temperatures warmed, terrestrial ice sheets transferred H_2O back to the world's oceans, raising their levels, expanding their volume, and subsuming coastal regions back into the hydrosphere.

At the peak of the Ice Age, 18,000 years ago, vast quantities of water lay frozen upon earthen surfaces at the expense of the world's oceans. Ice sheets stretching as far south as present-day Cairo, Illinois radically changed the topography and hydrology of the North American continent, re-sculpting the Missouri River drainage system to the west and the Ohio River system to the east such that the two rivers joined at Cairo. Rising global temperatures then melted the glaciers and sent increasing amounts of water and sediment to that confluence. There, at the apex of an immense downwarping of the Earth's crust known as the Mississippi Embayment (forerunner of the Lower Mississippi Valley), a dramatically augmented Mississippi River delivered increasing quantities of sediment-laden water toward the Gulf of Mexico. Minor bluffs and terraces constrained the river to meander within a wide, flat alluvial valley until it passed below a line roughly between present-day Lafayette and Baton Rouge, where gulf waters lay. When moving water laden with sediment suddenly meets a slack water body, it loses its kinetic energy and dumps its sediment load. Alluvium began accumulating as a deltaic lobe at the mouth of the Mississippi, turning salt water into saline marshes and protruding the coastline into the Gulf of Mexico. Future southeastern Louisiana was beginning to form, approximately seven millennia ago.

As that alluvial deposit rose in elevation, the Mississippi sought paths of less resistance around it, and in doing so formed a new channel and extended the coastline outwardly in a new direction. The first deltaic lobe, if no longer replenished with soil and fresh water, would subside and erode back into the sea, as the new active delta grew nearby. Seasonal floods would spill muddy water beyond the banks of the river, depositing more sediment along its inundated flanks and raising still higher the height of the active delta.

Occasionally a *crevasse* (breach) opened in the bank, allowing a trickle, or a torrent, or even the entire water column to divert from the main channel and into adjacent wetlands, instigating the same land-building process in yet another area. The mouth of the Mississippi River in this manner extended farther and wider into the Gulf of Mexico, creating a network of active and abandoned complexes—a deltaic plain—

that would eventually become southeastern Louisiana and home to New Orleans.

One visitor arriving to New Orleans in 1828 observed delta-building processes forming the marshy eastern flanks of the city. "[W]e coasted along, past numerous small, sandy islands," he wrote, "over shallow banks of mud, and through several immense basins, such as Lake Borgne and Lake Pontchartrain, half fresh, half salt, and filled with bars, spits, keys, and . . shoals [typical of areas] whose Deltas *are silently pushing themselves into the sea, and raising the bottom to the surface* . . . ."[7] To the French geographer Elisée Réclus, who sailed up the river in 1853, those processes created a deltaic plain which resembled "a gigantic arm projecting into the sea and spreading its fingers on the surface of the water."[8] 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."[9]

Geologists have, since the 1930s, generally agreed on where this "hand" landed over the millennia, though its exact extent, movements, eras, and "fingers" (lobes) have been debated and refined (see map, "Deltaic Complexes of Southeastern Louisiana"). In the 1940s, geologists R. J. Russel 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 that time was that the complexes, and thus the age of southeastern Louisiana, spanned roughly the last 5,000 years. 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. Sediments also layered the future New Orleans area during the years of the Plaquemines and Balize Delta, 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, David E. Frazier advanced the science with radiocarbon dating and other new technologies. Frazier identified five deltaic complexes of the Mississippi River, subdivided them into sixteen lobes, determined that many functioned contemporaneously, and estimated that the entire land-building event transpired over 7,200 years. Other scientists have since added to the body of knowledge on the origins of southeastern Louisiana, but, according to geologist Roger Saucier, "Frazier's work remains the most definitive to date."[10] According to that research, 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 aligns with earlier investigations.

New Orleans, then, stands not on the ancient, solid North American lithosphere, but on a thin, soft alluvial "doormat" cast recently out upon the continent's margin. Founded in 1718, the city has occupied this earthen surface for roughly 6 percent of the lifespan of its underlying geology, something few other major cities can claim. Certain live oak trees growing in City Park today have been around for about one-tenth the age of the landscape; some aged citizens have personally witnessed fully one-fiftieth of the city's geological existence. Not only is New Orleans' terrain the youngest of any major American city, but southeastern Louisiana is—as Mark Twain put—"the youthfulest batch of country that lies around there anywhere" in the nation, and the entire lower Mississippi Valley, from Cairo to the sea, possesses the continent's youngest surface soils.[11]

By the time of French exploration, around 1700, most of the region's landscape formations had reached a stage recognizable today. The passes, bays, bayous, lakes, natural levees and backswamps which currently grace maps with Francophone names were in place and known well by the Native Americans and French colonists. But these features, at the dawn of the colonial era, were still geologically alive and shifting, driven by gravity, 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 flowed toward the old Lafourche Delta to inspire early French explorers 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.

All this geological dynamism is anathema to human settlement. Over the next 300 years, humans would seize this malleable and watery land and rework it to improve the safety and circumstances for the time frame in which they live: the moment and the immediate future. New Orleans as an urban system has since become one of the world's great engineering challenges, and southeastern Louisiana and the lowermost Mississippi River rank as one of the most anthropogenically altered regions in the hemisphere. Every blessing seems to be accompanied by a curse, every solution seems to spawn a future problem. The historical geography of New Orleans is, in large part, the story of the benefits, costs, and constant dilemmas associated with this geological tinkering.

The Topography of Ooze

The high stakes of low elevation

> You will observe that the land [around New Orleans] is of peculiar formation. Throughout nearly the whole country, the bank of a river is the lowest spot; here, on the contrary, it is the highest.[12]
>
> —Father Vivier, 1750

Modern New Orleans is the lowest-lying and flattest metropolis in the nation. But both notions need further qualification.

Firstly, this deltaic city is not entirely "below sea level," as was proclaimed incessantly by pithy journalists and newly minted pundits following the Hurricane Katrina levee catastrophe of 2005. In fact, the prehistoric deltaic plain lay entirely *at* or *above* the level of the sea before man's recent interventions strangled off incoming sediment-laden fresh water and starved it into subsidence and erosion. Today, after decades of soil sinkage and rising seas, the metropolis straddles mean sea level: 51 percent lies at or slightly above sea level and 49 percent falls below it (see map, "Topographic Elevation of Metro New Orleans"). Higher natural areas generally slope up to about +10 to +12 feet in elevation, with man-made areas peaking at +25 to +40 feet; lower zones dip to -5 or -10 in some neighborhoods, with some canal bottoms dropping to –15 feet or lower.[13] This partial sunkenness is unquestionably a problematic situation, but nowhere near as troubling as the unconditional phrase "below-sea-level city" implies.

Secondly, while the landscape may appear absolutely flat, its slight relative differences in elevation have deeply influenced the city's urban development. The reason: in a flood-prone coastal region, topographic elevation is a scarce resource that is in high demand for the protection it affords. A few inches here are as valuable as ten or a hundred feet might be in a hilly city. Barely perceptible elevations in New Orleans have influenced whether a neighborhood developed during the Napoleonic Age, the Jazz Age, or the Space Age. They also determined (along with levee-breach locations) which neighborhoods were flooded by Hurricane Katrina's surge and which were spared, oftentimes to the amazement of residents. "This is a little island," marveled one Esplanade Ridge man whose house evaded inundation because of its topographic perch. "Five blocks away, there was eight feet of water."[14]

The highest areas of the deltaic plain lie closest to the rivers and bayous—exactly the opposite, as Jesuit priest Father Vivier marveled in 1750, of erosion-formed areas. The Mississippi historically overflowed in the springtime, depositing largest quantities of the coarsest sediments immediately upon the banks of the river, with lesser amounts of finer-grained sediment settling away from the river. In time, areas closer to the river (natural levees) rose higher than riparian areas behind them (backswamp). This occurs in all alluvial and deltaic environments. Le Page du Pratz described the process in his 1758 *History of Louisiana*: the soils of this area, he wrote,

> are brought down and accumulated by means of the ooze which the Missisippi carries [during] its annual inundations; which begin in [early spring] and last for about three months. Those oozy or muddy lands easily produce herbs and reeds; and when the Missisippi happens to overflow the following year, these herbs and reeds intercept a part of this ooze, so that those at the distance from the river cannot retain so large a quantity of it, since those that grow next [to] the river have stopt the greatest part.... *In this manner[,] the banks of the Missisipi became higher than the lands about it.*[15]

Occasionally, a crevasse would develop along the high river bank, diverting a stream of water away from the river and through the backswamp. These "distributaries" formed natural levees of their own by dispensing "ooze" along their banks, thus forming ridges and eventually dividing hydrological basins into sub-basins. The major distributary in the New Orleans area once flowed out of the river near present-day River Ridge, and wended its way eastward to the sea. Its flooding cycle created a slight ridge—"a certain bulge, called in 'hill' in these parts... imperceptible to the naked eye, [perhaps] one meter high," according to visiting geographer Elisée Reclus.[16] The main channel of the Mississippi River once followed this path (now traversed by Metairie Road, City Park Avenue, Gentilly Boulevard, and Chef Menteur Highway), creating the present-day Metairie and Gentilly Ridge systems. Its offshoot, the Esplanade Ridge, comprises a slight upland beneath today's Esplanade Avenue from City Park to the French Quarter.

During the 1700s-1800s, the natural levees of the Mississippi and its distributaries formed the only well-drained habitable land in the region. Urban civilization in historic New Orleans was existentially correlated with topographic elevation; higher land meant relative safety, security, salubrity, beauty, comfort, even morality. Listen to Pierre Clément de Laussat, Louisiana's last French administrator at the time of the Louisiana Purchase, describe an excursion in 1803 on the well-drained Metairie Ridge system of present-day Jefferson Parish:

> I organized a trip on horseback along the Metairie road, toward the plantation of the three Hazeur brothers, real French knights. . . . [T]he day was delightful, the sky serene, and the breeze from the northeast cooled off the heat of the sun. Trees were still thick with foliage. . . . Evergreens[,] [m]agnolias, vines, oaks, wild grapes, a great number of shrubs heavily laden with fruit all form a lovely sight deep in the heart of these uninhabited wastelands and forests. Sprinkled here and there are log cabins and some cultivation. And most everywhere it is alive with herds and multitude of curious birds.
>
> Sundays were generally observed as holidays. . . . Whoever had a horse or a carriage was on [Metairie] road. Strollers dressed in their Sunday finery were many. Young folks everywhere tried their skills [while] Negroes and mulattoes… challenged each other to *raquette des sauvages*. . . . The road was full with an unbroken line of traveling coaches, *cabriolets*, horses, carts, spectators, and players.[17]

Contrast Laussat's festive foray on the Metairie Road topographic ridge with the following anonymous description, circa late 1840s, of the barbaric lowlands:

> This swamp is several miles wide, skirting the rear of the city… and into this mud hole, water and filth (what little passes off) are taken. This boiling fountain of death is one of the most dismal, low and horrid places, on which the light of the sun ever shone. And yet there it lies under the influence of a tropical heat, belching up its poison and malaria, [which sweeps] through the city, feeding the living mass of human beings who stand there [with] the dregs of the seven vials of wrath. . . . Another evil is, the city, by the bend of the river, is thrown so near the swamp [that] it is almost entirely under water… after a heavy shower, [and] becomes covered with a yellow greenish scum. . . . [18]

"The backswamp," "the woods," *prairies tremblantes*, "the quarter of the damned:" low elevation formed a landscape of threat and fear for residents of eighteenth- and nineteenth-century New Orleans, depriving the community of arable land and living space while imparting miasmas and maladies. "[M]alignant disease," explained Thomas Ashe in 1809, "is generated by the lakes, swamps, and marshes, contiguous to the sea, and gradually diffuses itself up the river till checked by high lands and a higher latitude. . . .”[20] “From land left saturated by receding floods, and from pools stagnating in sunken lots on the outskirts of cities,” read an 1877 medicine advertisement, “rises a vapor pregnant with disease. Its name is miasma, and it is laden with the seeds of fever. . . .”[21] This was the perception of the day. Perception drives reality, and reality meant striving to modify this hated topography as much as technology allowed.

Humans have altered the topographic elevation of New Orleans primarily for four reasons: to keep water out, to improve navigation, to remove water from within, and to create or shore up land (see later readings on all four of these topics).

Keeping river and lake water out of the city motivated the region's most influential landscape manipulation: the erection of artificial levees on the crest of the natural levees to prevent springtime overbank flooding of the Mississippi. Similar earthen embankments were later built along the Lake Pontchartrain shore to prevent lake water from inundating the city from the rear, and across the marshes (hurricane-protection levees) to protect the flanks. These man-made levees now rank among the highest earthen features in the region, though soil subsidence renders them slightly lower every year. Some failed during Hurricane Katrina, leading to catastrophic flooding of about half of the metropolitan area and over three-quarters of New Orleans proper.

The economic drive to accommodate shipping—the second motivation for topographic change—resulted in the excavation of navigation canals such as the Carondelet Canal (1794), New Basin Canal (1838), Industrial Canal (1923), and the Mississippi River-Gulf Outlet Canal (1960s), the first two now filled in, the latter two all too much part of the cityscape. While these waterways and their paralleling docks and wharves abetted the city's role as a port, they also served to divide the natural hydrological sub-basins into smaller ones, and to penetrate and score the metropolis with potentially deadly aqueous connections to surge-prone gulf waters. So too did a number of drainage (outfall) canals dug near the lakefront as part of the late-nineteenth-century effort to drain water from within the city.

As a result of anthropogenic topographic alteration, New Orleans' landscape, naturally sectioned into four sub-basins by the Metairie, Gentilly, Esplanade ridges and the natural levee of the Mississippi, today comprises roughly a dozen different hydrological sub-basins. Some are impounded by natural features, others by man-made features; all straddle the level of the sea to some degree, and all require mechanized pumps and outfall canals to relieve them of rainfall. That's because nature has no way of pushing water uphill—and uphill it must go, because the aforementioned topographic alteration has inadvertently deprived New Orleans' soils of replenishing water and sediment, causing half of it to sink below sea level.

As valuable as topographic elevation is to this nearly flat and flood-prone city, it is by no means the sole factor determining flooding potential. The safety of the entire metropolis depends, first and foremost, on the protection entailed by levees, floodwalls, drainage systems, and coastal wetlands. An above-sea-level home located in a hydrological sub-basin that suffers a levee breach, a pump failure, or a clogged drain is perfectly capable of flooding, even as below-sea-level areas in adjacent basins remain dry. This happened during Katrina: higher-elevation parcels in the Lower Ninth Ward neighborhood of Holy Cross flooded because of the severity of the levee failures east of the Industrial Canal, while lower-elevation areas west of the canal were spared because those levees fared better.

Nevertheless, because we cannot forecast where levees or pumps might fail and which basins might inundate, we are left with the one variable that we can predict: water seeks its level and inundates lowest areas first. Higher elevation (either topographic or structural) means that a particular household will either evade floodwaters altogether, or at least suffer lesser water depths, than its lower-elevation neighbors situated within that same flooded basin.

Meager topographic elevation thus forms a precious and scarce resource in this water-logged environment, and, as such, has influenced New Orleans' historical geography much like water scarcity has sculpted the history of the topographically rugged American West.

“Mud, Mud, Mud”

Soils as a stealth factor to New Orleans' historical geography

Pedologists—soil scientists—find below New Orleans thin layers of extremely finely textured alluvial soils, high in water and organic content, recent in their formation, and highly vulnerable to transformation though human activity. The particles derive from various parent materials scattered throughout the 1,243,700-square-mile Mississippi Basin, delivered here via the transporting, sorting, and depositing functions of the Mississippi River. The river carries about one billion pounds of sediment past New Orleans daily, a journey that starts in the uppermost reaches of the Mississippi and its tributaries.

Some particles erode into the system as stones (>75 mm in diameter), which settle quickly due to their weight. Others, from 75 mm to 2.0 mm (gravel) make it much farther down the system. Finer particles, measuring from 2.0 mm to 0.05 mm (sand), travel haltingly all the way to the Gulf of Mexico, settling in the bedload during times of low flow and remobilizing during high springtime flow. Silt (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 into the Gulf of Mexico in vast quantities. Only the finest, lightest sediment particles survive the pull of gravity and make it to the New Orleans region.

“At New Orleans there is nothing scarcer than stones,” wrote one visitor in 1750. The alluvial soils forced Europeans to adapt traditional construction methods to new environmental conditions. “[B]ricks made on the spot are substituted for [stones].

Lime is made from shells, which are obtained [from] the shores of lake Pontchartrain. Hills of shells are found there [as well as] two or three feet below the surface" farther inland.[22] "An alluvial soil cannot be supposed to abound in rock," explained Maj. Amos Stoddard in his 1812 *Sketches, Historical and Descriptive, 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."[23]

As the Mississippi River historically flooded the New Orleans area and deposited water and sediment upon its swampy surface, coarser (heavier) sediments tended to settle first at the crest of the natural levee, with finer and lighter particles settling progressively farther back from the river. Basil Hall, a geographically savvy visitor from Edinburgh, described this process beautifully as he sailed down the Mississippi from New Orleans in 1828:

> The effect of [the river's] overflowing is most interesting in a geological point of view. The larger materials, that is to say, the coarser grains of mud—for there is hardly any thing like sand—are first deposited, then the less coarse, and so on. In proportion as the velocity of this surplus water is diminished, by finding room to spread itself to the right and left, so will the materials which it carries along become finer, and in smaller quantities. Thus, a sort of natural embankment [forms] from the edge of [the Mississippi] towards the swampy country on either hand.[24]

The high, relatively well-drained natural levees are thus made of some sand (Hall overstated its rarity), much silt, and some clay. The sloping lands behind them comprise little sand, mostly silt, and more clay. The lowest areas in the backswamp are made of no sand, some silt, and mostly clay. As one moves away from the river, the amount of water and organic matter in the soil body increases, and the water table rises closer to the surface. Strewn throughout the soil body are layers of organic matter, such as decaying leaves and cypress stumps. Also found are relic barrier islands, such as the Pine Island Trend, a sandy deposit of the Pearl River which drifted westward with gulf currents before riverine sediments turned the water around it into land. Architect Benjamin Latrobe, while investigating the city in 1819, described the earthen gumbo of New Orleans soils and understood clearly its relationship with the river:

> Mud, mud, mud … [T]his is a floating city, floating below the surface of the water on a bed of mud …. The upper surface … is a marsh mud, extremely slippery [when] wet, with a small mixture of sand, & below this surface are decayed vegetables, water at 3 feet … abounding in large logs, or in large vacancies [from] logs which have rotted. Such a soil [is] the result of the gradual accumulation of the deposition of the river, & of the logs & trees which in astonishing quantities & of immense size are constantly descending the stream at every fresh.[25]

The soils of New Orleans have informed the city's historical geography through two general precepts. The *closer* to the river (or its distributaries), then the coarser the soil texture, the higher the land surface, the lower the organic matter and water table, the less the salinity, and the better drained and more fertile the soil. *Therefore,* the greater the likelihood the area was once a plantation, the earlier the area was subdivided and urbanized, and the more likely it is now home to historical neighborhoods with eighteenth- or nineteenth-century architecture. Most of what people perceive as "classic New Orleans" stands on these soils, which go by the names of Commerce and Sharkey loams, among others.

The *farther* from the river (or its distributaries), then 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). *Therefore,* the less likely the area once hosted plantations, the more likely it urbanized later, the more likely it has subsided significantly once drained, the more vulnerable it is to flooding, and the more likely it exhibits twentieth-century architecture. Most modern suburban-style neighborhoods stand on these soils, among which are Harahan clay and the appropriately named Allemands Muck.

Soils have also helped make New Orleans an expensive place to urbanize. Transforming a natural landscape into a cityscape is a costly endeavor anywhere, but particularly in a semi-tropical deltaic environment with soft alluvial soils and a complex human history. A City Planning and Zoning Commission report from 1927 contended that New Orleans encountered "much higher [urbanization costs] than in other cities built on different terrain." Initial surveying, for example, is complicated by continued use of "the French system of measurement" and "the antiquity, inadequacy and inaccuracy of records," not to mention the difficult terrain. Clearing dense forest and underbrush is more demanding here than elsewhere, while excavating hydric soils often means encountering enormous old cypress stumps lying layers-deep in the mucky earth. Then comes the costly engineering challenges of keeping unwanted water out (flood control), removing unwanted water from within (drainage), guiding potable water in one direction, and directing sewerage out the other. Finely textured soils loaded with organic matter and prone to sinkage make the grading and paving of streets and sidewalks that much more expensive. Underground infrastructure, namely sewer, gas, and water lines, also contends with the above soil-related problems. Large structures need to rest upon pilings hammered into the earth to keep from leaning, while high-rises require specialized pilings penetrating into hard suballuvial Pleistocene clays to remain upright. Add to this the effects of humidity, high rainfall, luxuriant vegetation growth, termites, mosquitoes, and occasional high winds and hard freezes to increase further the costs of urbanization. In the 1920s, New Orleans spent more per-capita on sanitation and streets than any major American city, not because it aspired to high standards but because it had to overcome a far more challenging starting point. (Incidentally, it ranked at or near the bottom in per-capita expenditures on public health, hospitals, schools, and libraries.)

Soils played a stealth role in the flooding following Hurricane Katrina in 2005. As water levels rose in the city's network of navigation and outfall canals, pods of peaty organic matter allowed water to penetrate beneath the levees lining those waterways. Burdened additionally with intense lateral pressure on the concrete-encased sheet-piling floodwalls, levees breached in multiple locations and catastrophically inundated every hydrological sub-basin on New Orleans' East Bank. After the waters drained and New Orleanians returned to their wrecked homes, among the debris they encountered were the stumps and root systems of ancient cypress trees, uprooted from swamp soils for the first time in centuries by the surging torrent.

Gray, Turbid, and Broad

Magnitude and significance of the Mississippi River

To state that New Orleans is inextricably linked to the Mississippi River—physically, geologically, historically, culturally, economically—is axiomatic. Human agency, of course, created the city *per se*, but the river created its underlying terrain, drew indigenous and colonial attention to the site, connected it to trade systems, nurtured its crops and industries, sustained it, threatened it, unified external influences, and diffused internal traits. Tracing the Mississippi from headwaters to mouth (see map, "Mississippi River Drainage Basin") helps place New Orleans in its true context—as a river and sea port, so dependent on the artery that every resident literally imbibes its waters every day, from cradle to grave.

Starting with the traditionally recognized headwaters of 1,475-foot-high Lake Itasca, the incipient Mississippi—"its name in the Indian language [signifying] Parent of Rivers, or the eldest Son of the Ocean," according to a 1787 report[27]—forms a placid current of clear, cold water at times only a few dozen feet wide coursing through north central Minnesota. Seventy-five miles downriver, its flow runs at 443 cubic feet per second (c.f.s.), the equivalent of a twenty-one-by-twenty-one-foot wall of water passing a line in one second.[28] The St. Croix, Wisconsin, Rock, Des Moines, and Illinois rivers, plus many smaller tributaries, augment that rate to over 105,000 c.f.s. by the time the Mississippi undergoes its first major transformation, at the confluence with the 2,565-mile-long Missouri River.

"Big Muddy," born as Red Rock Creek in the Montana Rockies, drains nearly half the entire Mississippi Basin and outdistances the Mississippi by 200 miles. Though it contributes only 13 percent of the Mississippi's eventual maximum flow, the Missouri supplies the lion's share of the system's sediment load, eroded from western mountains and plains. Its confluence near St. Louis transforms the Mississippi to a muddy and turbulent river of 191,000 c.f.s. English traveler Charles Joseph La Trobe described the roiling convergence in 1833:

> [Our] boat glided suddenly from the clear water into a turbid yellow stream in which the mud could be seen boiling from below [which subsequently] disappear[ed] for nearly ten miles. The surface of the river showed little or

no token of the adulteration of the current; and it was not till we got ... within a few miles of St. Louis, that we observed the two rivers, distinguishable from their difference of colour, flowing for a while distinctly side by side, till in fine mingling their waters they form one immense torrent.[29]

An even greater transformation occurs at Cairo, Illinois, where the Ohio River doubles the Mississippi's volume to over 484,000 c.f.s. Above Cairo, the Mississippi flows in a relatively well-defined channel through a bluff-lined valley one to six miles wide. Below Cairo, the river 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. Father Vivier of the Society of Jesus described the terrain, biota, and native ecological intervention along this section of the river in 1750:

> Both banks of the Mississipi are bordered ... by two strips of dense forests [beyond which] the country is more elevated, and is intersected by plains and groves [with] thinly scattered [trees]. This is partly due to the fact that the Savages set fire to the prairies toward the end of the autumn, when the grass is dry; the fire spreads everywhere and destroys most of the young trees. This does not happen in the places nearer the river, because, the land being lower, [is] more watery....
>
> The plains and forests contain wild cattle [American bison], which are found in herds; deer, elk, and bears; a few tigers, numbers of wolves, wild-cats; wild turkeys and pheasants; and other animals, less known and of smaller size. This river [is] the abode of beavers, of a prodigious number of ducks, [plus] teal, bustards, geese, swans, snipe; and of some other aquatic birds, whose names are unknown in Europe, to say nothing of the fish of many kinds....[30]

By the time it flows past the loess bluffs (hills of wind-blown silt) of Vicksburg and Natchez, the Mississippi River reaches its peak single-channel volume, averaging 602,000 c.f.s. and surpassing 1,000,000 c.f.s. in high water years—a theoretical foot-thick wall of water one-thousand feet wide and one-thousand feet high passing every second. "The Mississippi flows gray, turbid, and broad," wrote the Swedish traveler Fredrika Bremer of this area on a wintry day in 1850,

> its waters become more and more swollen every day, and the shores become still more flat and swampy, bordered with cotton-wood and cane-brake. Great blocks of timber, trees, and all kind of things float along the Mississippi, all telling of wreck and desolation. This great river seems to me like the waters of the [biblical] Deluge, and they bear along with them a vast register of sin.[31]

About fifty river miles south of Natchez, the Mississippi changes character for a third time. Historically, the Red River joined the Mississippi here while the Atchafalaya flowed out of the system as a distributary to the Gulf of Mexico. In the 1830s, Louisianians, in the interest of navigation, manipulated this hydrology by excavating shortcuts, clearing logjams, and dredging shoals. In doing so, they inadvertently allowed a steadily increasing flow of Mississippi water to escape down the Atchafalaya. Within a few decades, suspicions arose that this may someday pose a problem. Nathaniel H. Bishop, an adventurer who canoed alone down the Mississippi in the 1870s, learned from a local planter that the Atchafalaya River "was slowly widening its current, and would in time, perhaps, become the main river of the basin, and finally deprive the Mississippi of a large portion of its waters." The planter, since his boyhood,

> had watched the falling in of the banks with the widening and increasing strength of the [Atchafalaya's] current.... Once it was impassible for steamers; but a little dredging opened the way, while the Mississippi and Red rivers had both contributed to its volume of water until it had deepened sufficiently for the United States gunboats to ascend it during the late [Civil] war. It follows the shortest course from the mouth of the Red River to the Gulf of Mexico.[32]

"Shortest course" to the gulf means *steepest* course, a hydrological characteristic that flowing water invariably seeks. By the mid-1900s, scientists recognized that the Mississippi would eventually jump channels—substantially, possibly entirely, around 1975—abandoning New Orleans and converting Louisiana's invaluable river corridor to an elongated brackish bay. The future of New Orleans was in question: a severed Mississippi would stifle river traffic and allow ocean salinity to creep up to the city's municipal water intakes. To prevent this catastrophe, Army Corps engineers built the Old River Control Structure in 1954-62 to regulate the flow of the Mississippi into the Atchafalaya at a government-approved seventy-thirty ratio. The viability of New Orleans as a port and a city rests on this Herculean engineering project.

From Old River to Baton Rouge, flat alluvial bottomlands stretch out to the west while soft, rugged loess bluffs line the eastern bank. Louisiana's capital stands upon the last of these uplands. "We have passed Baton Rouge," continued Fredrika Bremer while sailing downriver in late 1850. "Situated upon a high bluff....

> The Mississippi is at this point very broad. There are in the river sand-banks and verdant islands. Its waters are now clearer [because] the sun shines; the scenery of the shores is pleasing and quiet: plantations, orange groves, white slave villages amid the green fields, extensive views beneath the mild heavens.... The river is full of vessels, steamers, boats, and barges. We are approaching the gay city of New Orleans.[33]

Below Baton Rouge, flowing around 465,000 c.f.s., the Mississippi River finally exits its alluvial valley—"walled" at this point by meager terraces to the east (marked today by Baton Rouge's aptly named Highland Road), and by minor uplands to the west near Lafayette. From here on, the river flows between natural levees rising ten to fifteen feet above its surrounding deltaic plain. It is an incredibly productive environment, and historical visitors invariably noted the change in both the physical and human landscapes. "The soil [of the delta] is a deep black sandy alluvial, of great fertility, and seems not to deteriorate by cultivation," wrote one observer in the late 1840s. "This whole coast along the river is now occupied by the sugar planter, and for nearly eight months in the year the eye of the traveler sees nothing before him but the wavering sugar cane, presenting one unbroken living landscape of the most beautiful green ever beheld…."

In these final 200 miles, the Mississippi River averages 2,000-3,000 feet wide, runs fifty to 200 feet deep, and flows at slightly below the rate gauged at Baton Rouge. No more tributaries join the river in this deltaic region (the last one enters in North Baton Rouge); this figurative *cordillera* is a shedder of water, not a collector. Sugar cane still grows today on the adjacent landscape, but at a fraction of the acreage of antebellum times, and less so with every passing year.

To sail down this section of the Mississippi today is to experience a massively tamed river; levees not only constrain and guide the channel but disassociate it from adjacent banks. Entirely different was the experience in colonial times. Jesuit Father du Poisson described grueling days and nights on the wild lower Mississippi around present-day St. John the Baptist Parish during in the late spring of 1727:

> We set out at the time of highest water; the river had risen more than forty feet higher than usual; nearly all the country is lowland, and consequently inundated. Thus we were exposed to the danger of finding no… land where we could cook and sleep. When we do find it… we begin by making a bed of boughs so that the mattress may not sink into the mud; then we spread upon it a skin…. We bend three or four canes in semicircles [to form a tent]; then we spread over this frail structure… a large canvass [*baire*]…. In these tombs, stifling with heat, we are compelled to sleep.
> We are much more to be pitied when we find no camping-ground; then we fasten the pirogue to a tree, and if we find an embarras of trees we prepare our meal on it; [else] we go to bed without supper[,] exposed through the whole night to the fury of the mosquitoes. By the way, what we call an *embarras* is a mass of floating trees which the river has uprooted, and which the current drags onward continually. If these be stopped by a tree… or by a tongue of land, the trees become heaped upon one another, and form enormous piles; some are found that would furnish [a French city] with wood for three winters. These spots are difficult and dangerous to pass. It is necessary to sail very close to the embarras; the current is rapid there and should the pirogue be driven against these floating trees it would immediately disappear and would be swallowed up in the water….
>
> This was also the season of the greatest heat, which was increasing every day[;] there was always a burning sun above our heads…. [T]he height of the trees and the denseness of the woods—which extend along the entire route, on both sides of the river—did not permit us to enjoy the least breath of air….
>
> But the greatest torture [is] the cruel persecution of the mosquitoes. I believe the Egyptian plague was not more cruel…. This little creature has caused more swearing since the French came to *Mississipi* [*sic*], than… in all the rest of the world…. [W]e are eaten, devoured; they enter our mouths,

> our nostrils, our ears; our faces, hands, and bodies are covered with them; their sting penetrates the clothing, and leaves a red mark on the flesh, which swells. . . .
>
> Such are the inconveniences of a Mississipi voyage.[36]

Only along certain banks and islands can one today experience a semblance of the untamed Mississippi. Even then, the water's channel, stage, flow rate, quality, sediment load, and biota would all reflect centuries of anthropogenic intervention. Even the mosquito population would differ: many species now in Louisiana were introduced since colonial times.

At River Mile 115, the Mississippi River enters metropolitan New Orleans and twists through it for the next twenty-seven miles. It is an especially wending section: two prominent "point bars" on the east bank, and three on the West Bank, have challenged navigators for 300 years. Point bars form on the concave side of a river meander, where the current slows and deposits sandy alluvium (*batture*) at the water's edge, extending the land outwardly. The term *batture* comes from the past participle of the French verb *batter*, "to beat," as in "beaten down by the river;" *leveé*, on the other hand, comes from *lever*, "to raise up." Battures figure prominently in Louisiana culture, both along the river and in the courthouse: what happened legally when a batture formed adjacent to private property oftentimes ended up in a lawsuit.

"The inhabitants consider themselves fortunate when a batture begins to form or continues to build up in front of their land," recalled Pierre Clément de Laussat in 1803. "But one bank builds up firmly only at the expense of the opposite bank, and a batture always means a bank cave-in [*éboulemens*]; one is always in proportion to the other."[37] The Frenchman was right: across the river from the point bar 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 in places such as Bywater and accreting on the west in Algiers. Army Corps levees, revetments, armoring, riprap, and other devices restrain the river from its normal functions, but the battle is ongoing—as are the legal cases involving batture ownership.

Ninety-five miles above the mouth sits the original city of New Orleans, where, coincidentally, lies the deepest point of the entire river, about 200 feet. Flow rates here typically range from 450,000 to 535,000 c.f.s. but can nearly triple during high water. Since consistent measurements have been kept, river stage in New Orleans has run as low as 0.71 feet above mean gulf level and as high as 19.98 feet, averaging about ten feet above the sea.[38] 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).[39] At those times—specifically when the river surpasses seventeen feet in stage or 1,250,000 c.f.s. in volume—the Bonnet Carré Spillway is opened to divert up to 250,000 c.f.s. into Lake Pontchartrain. During extreme floods, the Morganza and Old River structures may also be activated to divert flow into the Atchafalaya River.

The sight from the levee of a swollen river gliding above the level of adjacent rooftops has long startled newcomers: “What struck me most,” wrote a visitor from Edinburgh in 1828, “was the [Mississippi’s] surface being six or seven feet higher that the level of the streets of New Orleans, and indeed of all the adjacent country.… [I]t seemed as if the smallest shake, or the least addition, would send it over the edge, and thus submerge the city.”[40] But, as often happens in New Orleans, majesty and awe accompanied that sense of threat. Another visitor, also in 1828, waxed eloquently on New Orleans’ future as he contemplated the great natural phenomenon before him:

> 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 of square miles. You may [sail for] 1000 miles from New Orleans up the Red river… up the Arkansas river,… up the Missouri and its branches… to the falls of St. Anthony; [and] the same distance from New Orleans up the Illinois… the big Wabash… the Tennessee… the Cumberland, and… 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 gulf 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.*[41]

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 a proximity to 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. This feature comprises six sub-deltas, numerous splays and lobes, and three major passes: Southwest Pass (50 percent of flow and the route of most navigation activity), South Pass (20 percent), and Pass a Loutre (30 percent), which branches into North and Northeast Pass. The Balize 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 and 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.”[42]

The Continental and the Maritime

Climate and weather in New Orleans

> Although the temperature was generally quite pleasant, its variations carried it rapidly from one extreme to the other.... One day may have been a real spring day; the following night would bring a violent wind.... The next day might be cold enough to call for heat; and the day after tropical.... A storm would break out, bringing [some] relief, [while] the mornings...were for the most part delightful. Such was May in Louisiana. We were to see what the summer months, about which people frightened us, were like.[43]
>
> —Pierre Clément de Laussat,
> recalling springtime in New Orleans in 1803

That the heat and humidity of a New Orleans summer constitute a "frighteningly" oppressive climate—indeed, that it is even hot and humid—reflects, of course, an anthropocentric perspective. Vegetation grows luxuriously under those very conditions that humans find oppressive; wildlife flourishes in the same subtropical coastal wetlands that people describe as inhospitable. Simply put, New Orleans' climate "is what it is:" inanimate atmospheric conditions produced by local, continental, or global processes. Its influence on local society, however, is profound.

Latitude constitutes the most fundamental climate factor. New Orleans' position at 30 degrees north places it 6½ degrees beyond that portion of the Earth—the tropics—that are exposed, because of the planet's 23½ degree tilt, to the most direct and concentrated solar radiation. On the summer solstice, the sun's rays strike the northern limit of the tropical region (the Tropic of Cancer) at a ninety-degree angle; in New Orleans, the rays arrive at 83½ degrees. Latitude dictates sun angle, sun angle drives solar radiation, and solar radiation increases temperature. If only latitude determined climate, New Orleans would experience warmer temperatures than all of North America except south Florida, south Texas, and Mexico. But three other factors are at play.

Position with respect to water bodies is a key one. Water serves as a "sink" for solar radiation as well as a source of water molecules to evaporate into the atmosphere. The tropically heated Gulf of Mexico warms the air mass above it and thence coastal lands near it, including New Orleans. Warmer air bears more water molecules, giving New Orleans a temperature and relative humidity higher than comparable inland areas of the same latitude. Temperatures would go no lower than the 60s in the winter were it not for the third factor driving climate: relative position on the continent.

Continental position exposes a place to certain prevailing winds and the conditions they bear. Winds in the mid-latitudinal northern hemisphere generally blow west to east, which means that the western parts of continents are subjected to warmer, more stable maritime climes, while eastern areas experience the more volatile continental conditions blowing in from the interior. Cold fronts, which arrive in lesser and greater intensities roughly once or twice per fortnight from late October through early April, drive autumn-to-spring weather conditions in New Orleans. Winter in particular is punctuated by the ebb-and-flow between warm, humid tropical air masses rising from the Gulf of Mexico and frigid, dry air masses arriving from the Rockies, plains, or polar region. This accounts for the city's notoriously varied wintertime weather, suffered by the likes of newly arrived English visitor Charles Joseph La Trobe during Christmas and New Year 1833-34:

> With a thermometer between 70° and 80°, and a constant drizzle... the streets were full of mud oozing up from the pavement, and it was a penance to be [in this] thick and unwholesome atmosphere.... [A]n impenetrable mist rested on the city, through which frequent flashes of lightning glimmered portentiously;—then came a terrific storm...but with no abatement of the heat till the ensuing night, when the thermometer fell below the freezing point.
>
> Three days after the country was covered with snow, and many miserable wretches were found dead in the streets.... It continued freezing for four days, when the atmosphere again regained the former degree of heat. Such a chaos of mud can hardly be conceived.[44]

(Although such weather extremes are typical from December through February, the snow and extended freezes reported by La Trobe are rare. Most cold fronts lose their frigid edge as they pass over the relatively warm waters of Lake Pontchartrain.)

Finally, topographic elevation—or in this case its absence—affects climate. Sea-level New Orleans bears zero altitudinal influence on climate (roughly 3.3 degrees F cooler for every thousand feet in elevation), but the lack of mountain ranges to the northwest is consequential, because cold fronts are able to arrive unobstructed. These interior influences make New Orleans' climate continental (read: wide range of temperatures and drier conditions), while proximity to the Gulf of Mexico renders it also maritime (read: usually relatively warm and humid conditions). The following conditions characterize New Orleans' humid subtropical climate:[45]

- Daytime highs in the 90s and nighttime lows in the 70s-80s during the hottest months (July-August);
- Low-60s daytime highs to the mid-40s nighttime lows during the coldest months (December through February), with extremes ranging from the low 80s to upper 10s;
- A season cycle defined mostly by cold fronts, with the first weak front marking the arrival of autumn (usually a few weeks after the equinox), the first strong front commencing winter (usually in late November), and the last strong and weak fronts passing in March and early May, respectively, ending winter and spring;
- A roughly 280-day growing season, with hard freezes occurring every few

years but some winters passing sans even a weak freeze;

- Relative humidity ranging from 65 percent on summer afternoons to 91 percent on summer mornings, and 66 to 85 percent on winter afternoons and mornings;
- An average of 62 inches of precipitation annually, with the most falling in summer (over 7" in July), the least in autumn (3.1" in October), and moderate amounts from December through May (around 5" per month);
- A norm of partly cloudy conditions, with sunlight reaching city streets during 60 percent of the drier months and around 45 percent of the wetter months. Clear days prevail 28 percent of the time; partly cloudy conditions comprise 32 percent, and cloudy days make up 40 percent of a typical year;
- Extremely rare snows, falling every decade or so and rarely amounting to more than a cold sleet or a dusting.

The impact of climate on New Orleans society is profound, but—excepting tropical storms—no more or less than it is wherever humans live. Climate allowed the large-scale cultivation of lucrative commodities, particularly sugar cane, for which New Orleans served enthusiastically as a trade and transshipment point. Architectural traits such as balconies, galleries, high ceilings, and steep roofs bear at least some provenance to climatic conditions. Summertime heat and humidity meant not only round-the-clock discomfit but the threat of death: a favorable climate enabled the African mosquito *Aedes aegypti* to establish itself here, spreading the yellow fever virus which killed tens of thousands of New Orleanians in the 1800s. Those of means, including Northern businessmen, responded by annually departing for more salubrious climes, leaving the summertime city disproportionately to Creoles (natives), immigrants, the poor, and the enslaved. One observer in the late 1840s estimated that, while the city's official population exceeded 100,000, "a transient population of thirty or forty thousand [departs] in swarms … as soon as the warm season commences, [and returns] as wild geese do from the North, on the first appearance of a flake of snow."[46] Thus, New Orleanians' response to climate seasonally altered the social, economic, ethnic, and racial dynamics of the city.

New Orleanians, in return, have influenced their climate. The urban heat island effect, in which the expansive concrete surfaces increase temperatures over metropolises, occurs in nearly all cities. Other environmental manipulations possibly affected local weather in more unusual ways. Englishman Thomas Hutchins recorded in 1760 that "winters [in Louisiana] have been more severe, for some years past, than they were commonly known to be at the time when the *French* first settled here, occasioned, as is thought, by clearing the lands of the woods … ."[47] Weather Bureau forecaster Isaac Cline, of Galveston hurricane fame, noted an eight-degree increase in summertime temperatures and a four-degree drop during winters between 1900 and 1918. His explanation:

> water absorbs heat more slowly than the earth during the day and loses it less rapidly at night. New Orleans, entirely surrounded by water and with

> its soil saturated, formerly boasted of a more uniform climate. In late years, however, levees have prevented overflows, reclamation projects have effected the draining of swamps and, finally, sub-surface drainage…has eliminated surface water from the street drains [and] ground moisture [by] eight or ten feet.[48]

If Cline's analysis is correct, then New Orleans, by draining its backswamp, rendered itself more of a continental and less of a maritime climate.

Modern technology has tempered the effects of climate on New Orleans society. Domestic air-cooling technology transformed local streetscapes and culture, as New Orleanians traded the social space of stoops and front porches for the private space of climate-controlled living rooms. Yet the cycle of life in the city today is still fundamentally attuned to climate. The first cold front in October brings an up-tick in the tourism and convention trade, which peaks during the wintertime Carnival season (weather on Mardi Gras is notoriously varied). "Festival season" kicks into high gear during the delightful late winter and early spring, and when the last tunes die down at Jazz Fest, everyone knows "the Big Heat" is approaching. As in times past—but for very different reasons—those who can leave in the summer, do. The other 99 percent count the days to the next cold front—while living in dread of a climatic phenomenon that occurs locally for all of a few hours per century, yet threatens the very survival of the city: severe tropical storms.

Of the scores of such tempestuous low-pressure systems to strike New Orleans (see *The Fortuitous Storm of 1722, The Great Storm of 1915, Hurricane Betsy,* and *Hurricane Katrina*), the hurricane of 1779 was the first to be characterized meteorologically for the scientific record. Writing about New Orleans' climate for the *Transactions of the American Philosophical Society*, William Dunbar reported,

> August and September are called the hurricane months.… I was at New Orleans during the [August 18, 1779 hurricane, in which] more than half of the town was stript of its covering, many houses thrown down in town and country, no ship or vessel of any kind was to be seen on the river next morning.
>
> The river…was forced over its banks, and the crops which were not yet collected, disappeared from the face of the earth. The forests [near] New Orleans assumed the dreary appearance of winter, the woods over large tracts were laid flat with the ground.…

Dunbar estimated that the storm spanned twelve miles and passed directly over New Orleans. He had the presence of mind to track the curiously changing directions of the wind:

> [I]t continued blowing from the East or S.E. for two or three hours with undescribable impetuosity, after which succeeded all at once a most profound and awful calm, so inconceivably terrific that the stoutest heart…could not look upon it without feeling a secret horror, as if nature were preparing to resolve herself again into chaos.… [After] 5 or 6 minutes, perhaps less, the

> hurricane began to blow from the opposite point of the compass and very speedily regained a degree of fury and impetuosity equal if not superior to what it had before possessed.

Dramatically, Dunbar recounted how dead bodies, which had earlier blown upstream on the Mississippi's surging waters, now sped downstream with such velocity that they were more airborne than waterborne. He concluded his paper,

> It is probable that if similar observations are made upon all hurricanes, tornadoes and whirlwinds they will be found universally to consist of a vortex with a central spot in a state of profound calm . . . .[49]

That observation, originating from New Orleans in 1779 and published in 1809 in one of early America's most influential scholarly journals, brought new scientific understanding to the phenomenon of tropical storms, and to the disciplines of meteorology and climatology.

New Orleans will figure prominently in the future of those and other scientific disciplines, given its front-line position vis-à-vis climate change, rising sea levels, eroding coasts, and other unfurling environmental dilemmas. In the meanwhile, weather patterns will continue to affect the daily life of New Orleans society as an ongoing battle between the continental and the maritime.