Chapter 13
Coastal Louisiana

Lynn Donelson Wright and Christopher F. D'Elia

> (The upper course of the Mississippi River)… *is held in place … by the gorge in the Commerce hills. Its mouth in the Gulf of Mexico is fixed by the works of man. Between these points it writhes like an imprisoned snake constantly seeking … equilibrium.*
>
> —D. O. Elliot, U.S. Army Engineer quoted by Barry (1998)

13.1 A Unique and Imperiled Coastal System

Just as "Egypt is the Gift of the Nile" (Chap. 4), Coastal Louisiana owes its existence entirely to sediments supplied to the Gulf of Mexico coast by the Mississippi River (Fig. 13.1) from a catchment that covers 3.2 million square kilometers (1.2 million mi^2) of North America including roughly 41% of the area of the contiguous 48 states of the USA (EPA 2017). Over the past 10,000 years, these sediments have yielded vertical accumulations of 0.1–0.5 km (0.06–0.3 mi) with the highest accumulations occurring nearest to river mouths (Coleman and Roberts 1988). As sediments have accumulated, the land surface has undergone progressive subsidence, partly because of large-scale tectonic subsidence of the structural Gulf Coast Geosyncline and partly because of compaction of the fine grained silts and clays. According to Allison et al. (2016), the rates of Mississippi Delta subsidence are up to 18 mm/year. When this subsidence is added to the projected rates of global sea level rise of between 8 and 16 mm/year, the total relative rate of sea level rise in coastal Louisiana will conceivably be between 26 and 34 mm/year or roughly up to 1 foot per decade (Chap. 3; Figs. 3.6 and 3.7). Prior to European settlement in Coastal Louisiana over the past two or three centuries, deposition of

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L. D. Wright and C. R. Nichols (eds.), *Tomorrow's Coasts: Complex and Impermanent*, Coastal Research Library 27,
https://doi.org/10.1007/978-3-319-75453-6_13

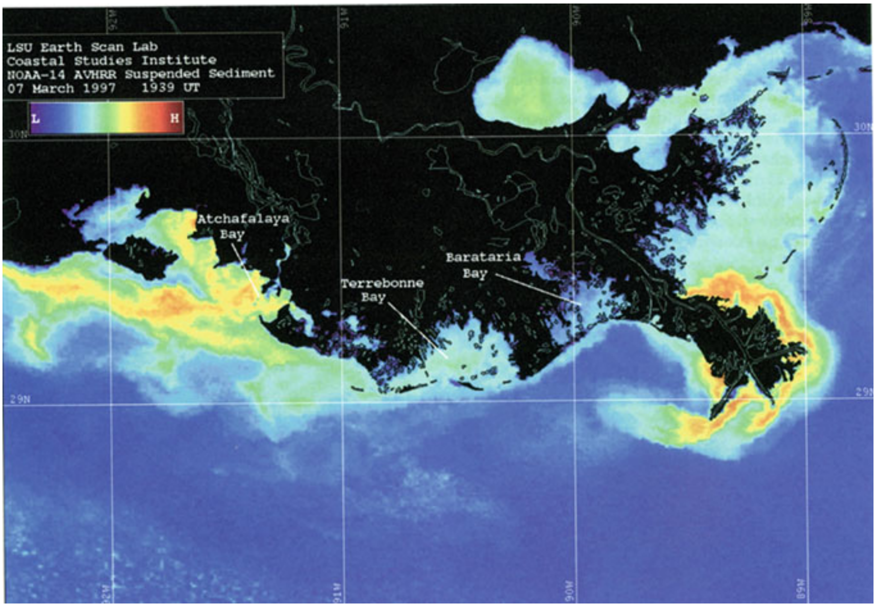

Fig. 13.1 The Mississippi Delta showing sediment plumes issuing from the mouths of the modern "bird's foot" delta lobe in the east and the Atchafalaya River in the west. NOAA AVHRR image from LSU's "Earth Scan" Lab, March 1997

new sediment was able to keep pace with subsidence by a combination of overbank discharge, crevasse splays and occasional avulsions of the river and its tributaries. However, since the early 1800 s, increasing engineering constraints have confined the river, reduced the amount of sediment reaching the delta, and greatly limited the natural dispersal of sediment over the deltaic surface. Today, land loss greatly exceeds land creation. As the area of open water increases, so does exposure to erosive wave action. At the present time, the rate of land loss is averaging 41 km^2 (16 mi^2) per year (or, as popularly stated: "one football field per hour").

Coastal Louisiana includes the largest wetland in the U.S.A. and one of the largest in the world. This unique and diverse ecosystem is regarded as one of the world's natural treasures. The cultural landscape is equally unique and diverse and includes, among its population of roughly 2 million people, long-time Native American residents, extensive African American communities, descendants of French and German immigrants, mixed race Creoles and Acadians ("Cajuns") who were originally displaced from Nova Scotia. In economic terms, up to $138 billion in business, residential, and infrastructure assets are at risk and could be lost by 2050; a single severe storm could cause disruption of $53 billion in economic activity (Barnes and Virgets 2017). Beyond conventional economic activity, Shepard et al. (2013) report that "In 2010, revenues from provisioning ecosystem goods and services generated by the five U.S. states bordering the Gulf of Mexico contributed over $2 trillion per year to the nation's gross domestic product, including $660 billion from the coastal county revenues and $110 billion from ocean revenues" (Shepard et al. 2013, p. 10). It is, perhaps, ironic that the extensive engineering works that were intended to protect people and assets from floods and support navigability of the lower Mississippi River are now profoundly implicated in the disappearance of the wetlands that once provided natural protections. Numerous dams on the upper reaches of the river have significantly reduced the amount of sediment that ultimately makes it to the coast. The levees that protect Louisiana communities from floods and storm surges also prevent sediments and nutrients from nourishing wetlands and agricultural lands. Prevention of the river and its distributaries from switching course, as is natural, does not allow sediments to be deposited in the western parts of the delta. The sediments remain confined to the river channels until they reach the river's mouths where man-made jetties maintain navigable depths by funneling the outflows and causing the much-needed sediments to be lost to the deep Gulf of Mexico waters. The dissolved nutrients that were denied to farmlands and wetlands upstream are now dispersed over the continental shelf where they contribute to eutrophication and oxygen depletion (Chap. 6, Fig. 6.3).

13.2 The Physical Setting of the Mississippi Delta

Today, the Mississippi Delta covers an area of 29,000 km^2 (11,200 mi^2). The rate at which the Mississippi River discharges fresh water into the Gulf of Mexico averages 15,360 m^3/s (552,960 ft^3/s) over the course of a year but reaches a maximum rate of 57,400 m^3/s (2,066,400 ft^3/s) when the river is at flood stage during spring. Annually, the river delivers 210 million tons of suspended sediment to the Gulf of Mexico (Milliman and Meade 1983). Compared to many major river systems, this is a fairly small sediment load; the Ganges-Brahmaputra system has an annual sediment load of 1.67 billion tons per year and the Amazon discharges 900 million tons per year. Although most of the Mississippi sediment bypasses the coastal wetlands that need it, much of the material that has not spilled over the edge of the continental shelf has accumulated on the shelf yielding an extraordinarily low gradient (slope of only 0°.02′) and soft inner shelf profile (Chap. 5, Fig. 5.2). For coastal Louisiana, this is both good and bad. It is good because the flat, muddy seabed causes wind-generated waves to be substantially dissipated before they reach the shore (Sheremet and Stone 2003). It is bad because low gradient shelves favor amplification of long-wave storm surges as was exemplified by Hurricane Katrina in 2005. The average wave height in deep water off the coast is about 1 m (3.3 ft) but is typically less than 20–30 cm (<1 ft) near shore. The maximum wave heights recorded by buoys offshore during storms have been up to 10 m ($\sim$33 ft) but less than $\sim$5 m ($\sim$15 ft) inshore. Tides and tidal currents are small. The tides are diurnal (1 tide per day) and the range is only 40 cm (1.3 ft) and since the tide only occurs once per day, the resulting currents are very weak. Consequently, vertical mixing between the low salinity river plumes and the higher salinity Gulf waters is weak allowing the mud-laden freshwater plumes to be carried westward

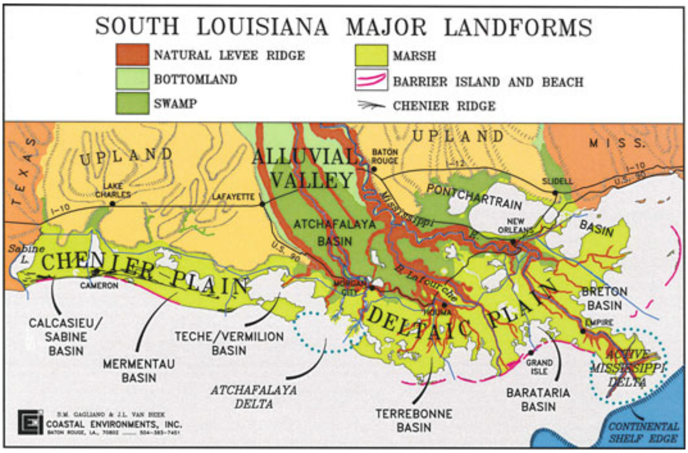

Fig. 13.2 The major geomorphologic regions of coastal Louisiana. Figure is from Gagliano and van Beek 1993 with permission from Coastal Environments Inc. Baton Rouge, LA

by the prevailing coastal currents which normally flow from east to west (Dinnel and Wiseman 1986).

Since the last post-glacial sea level rise reached its current position about 7000 years ago, the lower Mississippi River has switched its course at least 6 times. Following each avulsion, the river produced a major deltaic lobe (Draut et al. 2005). These overlapping lobes have left behind what now constitutes the rapidly receding deltaic plain of the Mississippi. The result has been the existing landscape (Fig. 13.2), which includes the remaining deltaic plain comprised mostly of disappearing wetlands and shallow bays. The western part of the deltaic plain includes the newly forming deltaic deposits from the Atchafalaya River, an active distributary of the Mississippi River. Further to west, is a plain of low beach ridges, locally referred to as "cheniers" because they are surmounted by oak trees (chene, in French). The Chenier Plain is composed of sediments transported westward from the active delta and pushed onshore from the inner continental shelf during episodic high wave energy events. Inland from the deltaic plain is the alluvial valley of the lower Mississippi River, which is incised within "uplands" consisting of older Pleistocene deposits.

13.3 The Cultural and Socioeconomic Landscape of Coastal Louisiana

In the broadest sense, the population of coastal Louisiana can be separated into two very general categories: those who live in and around New Orleans and those who do not. New Orleans proper covers an area of 170 square miles (440 km^2) and has roughly 400,000 permanent residents (U.S. Census Bureau 2016). African Americans make up 60% of the population, whites account for 33% and Hispanics a little over 5%. In the mid 1800 s, New Orleans was the wealthiest and the third largest city in the U.S.A. Today, the average per capita income of the city is $27,700 (USD) and 27% of the population is living at or below the poverty level making them highly vulnerable to floods and severe storms. The loss of protective wetlands has greatly increased this vulnerability (Tibbetts 2006). This historical and architecturally unique city attracts large numbers of tourists and tourism, including hotel accommodations and food services, generates $2.8 billion (USD) in annual revenue. It is largely for this reason as well as the vulnerability of the population that the U.S. Army Corps of Engineers has invested $14.5 billion in surrounding this sinking city, which is already below sea level, with an elaborate flood protection system consisting of hardened levees, floodgates, storm surge barriers and high-volume pumps. It should be noted that, when one considers the urban "agglomeration" immediately surrounding New Orleans proper, including the eight contiguous parishes, the total population swells to 1.3 million (in year 2000; U.S. Census Bureau) and the demographic composition becomes more similar to that of the state as a whole.

Beyond the "Big Easy," Coastal Louisiana includes extensive rural lands, wetlands, bayous, and several other cities including Lake Charles, Abbeville, Lafayette, New Iberia, Morgan City, Houma, Thibodaux and Cameron as well as barrier island communities like Grand Isle (Fig. 13.2). About 63% of the inhabitants are white and 32% are African American. French speaking Cajuns (Acadians), Creoles and direct descendants of French and Haitian immigrants make up a high percentage of the population and many of these residents are involved in commercial fishing (which supplies 26% by weight of U.S. commercial fisheries landings) or agriculture. Many others are employed by the oil and gas industry, which supplies 18% of the nation's oil (CPRA 2017). Although their populations are relatively small, there are also unique and threatened Native American tribal communities, primarily of the Choctaw and Muskogee Nations, throughout the lower Mississippi River Delta. Many of these communities have lived in the delta for up to 300 years, existing on a subsistence economy. Some notable examples include Grande Bayou Village in Plaquemines Parish and the Pointe-au-Chien Tribal Community in Terrebonne Parish (Peterson 2012).

The dominant economies to the west of New Orleans are oil and gas, commercial and recreational fisheries and agriculture. Shipbuilding and boat building are also significant in specific localities. The oil and gas industry accounts for over 25% of the total revenues collected by the state of Louisiana (NRC 2006). In addition to being a major producer of oil and gas, much of it from offshore production platforms, Louisiana is among the nation's top 3 importers of crude oil (U.S. Energy Information Administration 2017). The "Henry Hub" is a natural gas delivery point where 13 major pipelines intersect. The Louisiana Offshore Oil Port (LOOP) is the only U.S. port facility capable of berthing Ultra Large Crude Carriers. Much of the oil imported via such facilities is processed by the 18 operating Louisiana petroleum refineries (U.S. EIA 2017). In the aggregate,Louisiana supplies 18% of the

Fig. 13.3 Port Fourchon, LA. A center of oil and gas activity near Houma and highly vulnerable to rising sea levels and future storm surges. From Barnes and Virgets (2017)

US's oil. The elaborate, multi-billion dollar infrastructure that supports this industry, mostly in the vicinity of Houma, LA (Fig. 14.3; Barnes and Virgets 2017) is now at serious risk of damage or destruction when future storms are superimposed on rising seas and sinking lands (Fig. 13.3).

Agriculture and commercial fisheries are also very important sources of income for residents of rural Coastal Louisiana. In 2005, agriculture in Louisiana's coastal parishes contributed $410 million to the state's economy (NRC 2006). The major crops are sugarcane, rice and soybeans. Freshwater pumped from bayous, such as Bayou La Fourche, provides irrigation for fields but progressive upstream penetration of sea water threatens the continuation of this practice. The smaller, family farms of the past are rapidly being replaced by large "agribusiness" farms. Louisiana is regarded by many as the U.S. seafood capital: second only to Alaska, it accounts for the nation's highest commercial fish landings and 37% of the nation's oysters. The wetlands serve as nurseries for these fisheries and their disappearance will have a very negative impact on commercial and recreational fisheries. Ironically, however, some in the seafood industry have expressed concerns that plans for reclaiming land from open bays could have a negative impact on some fisheries including oysters (NRC 2006).

13.4 Hurricanes and Storm Surges

From an analysis of tropical storm and hurricane landfalls in the Northern Gulf of Mexico, Doyle (2009) concluded that storm frequency is greatest along the Florida Panhandle and decreases toward the west becoming half as frequent along the Texas coast as in West Florida. Nevertheless, over the past century or so Louisiana has taken direct hits by some very intense and destructive hurricanes. According to Roth (2010) in a technical report of the National Weather Service, some of the deadliest and most destructive hurricanes to hit the U.S. have made landfall on the Louisiana coast. Notable examples were Audrey in 1957, Betsy in 1965, Camille in

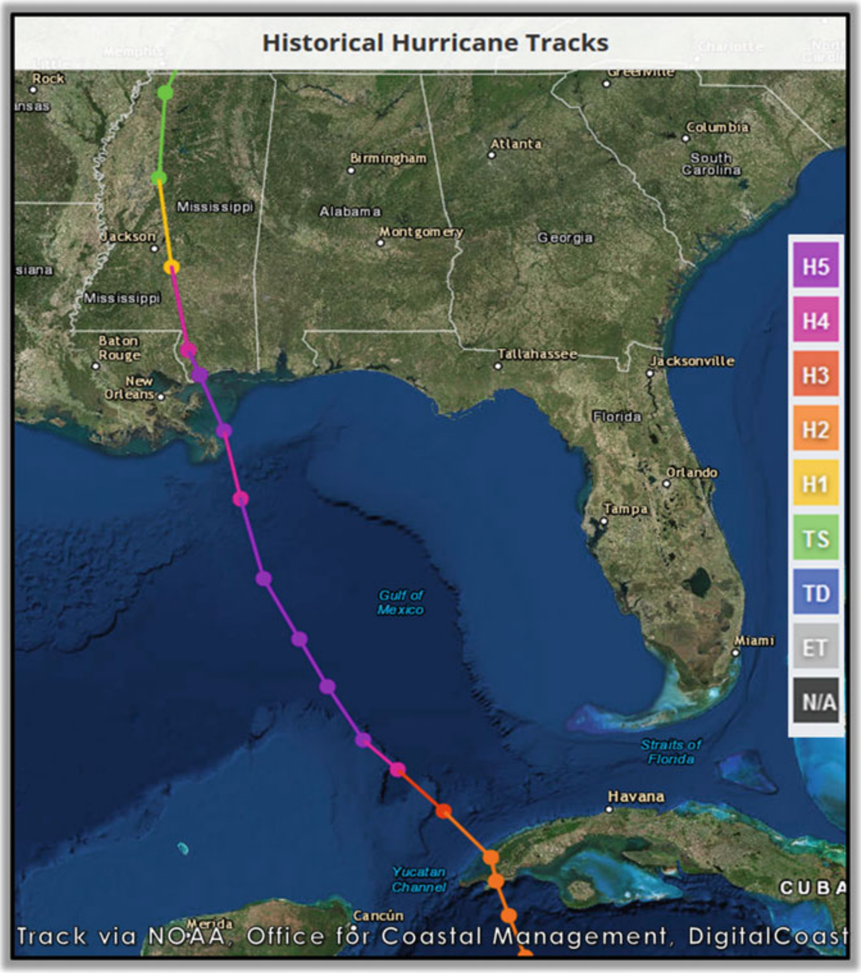

Fig. 13.4 Northward track of Hurricane Camille up the Gulf of Mexico to landfall in the Mississippi Delta in mid August, 1969. Image from NOAA Office of Coastal Management, Digital Coast

1969, Andrew in 1992 and Katrina in 2005. Between 1850 and 2010, a total of 106 tropical cyclones made landfall on Louisiana's shores (Roth 2010). The most intense storm of the 20th Century and early 21st Century was Category 5 Hurricane Camille (Fig. 13.4) in August 1969, which struck Plaquemines Parish along the narrow strip of the modern delta lobe with 160 mile per hour (256 km/h) winds and completely leveled the towns of Venice and Buras. Camille also severely damaged coastal counties of Mississippi and Alabama. The warm waters of the Gulf of Mexico contributed to the intensification of Camille as it progressed northward.

Although it was less intense than Camille, Hurricane Katrina caused far more damage, loss of life and general devastation in eastern Louisiana than Camille, primarily because of losses of protective wetlands over the 36-year period separating the two storms. Less than 4 weeks after Katrina, Hurricane Rita made landfall near the Louisiana-Texas state line inflicting damage on the western part of Louisiana's coast.

Although it is the direct impact of winds that cause damage to, and destruction of buildings, it is coastal flooding that causes the most fatalities as well as much property damage and substantial human health hazards (Chap. 10). The two most common causes of coastal flooding are storm surges and heavy rainfall (as exemplified by hurricane/tropical storm Harvey in August 2017). In some cases, river floods that coincide with storms can add to the effects of surges. In the case of the Pearl River Delta (Chap. 12), heavy rainfall can cause more severe flooding than storm surges. But, in the case of Coastal Louisiana it is storm surges that are most devastating and this was very much true of the hurricane that drowned 6000 people in Galveston in 1900 (Chap. 10). Needham and Keim (2011) compiled a data base on storm surges that have affected the northern Gulf of Mexico and point out that the most severe storm surges in the U.S. occur along the Gulf Coast. The torrential rainfall flooding of Texas and Western Louisiana by Harvey in 2017 may well represent the onset of a new regime.

The low gradient inner continental shelf combined with the trapping or funneling effects of convergent bays such as the Bay St. Louis area immediately east of the active "Birds-foot" delta causes the long-wave surge to experience amplification as it moves ashore. The results of Needham and Keim's (2011) analysis show that surges affecting the Florida panhandle are much less severe than is the case for the crenulated and embayed Louisiana coast. Although Hurricane Andrew that made landfall just south of Miami in 1992 was a Category 5, it caused a maximum storm surge that was typically less than 2 m high (4–6 ft.) throughout most of Biscayne Bay reaching a local maximum of 5 m (16.5 ft; Chap. 15). The weaker Hurricane Katrina over the shallow shelf of the northern Gulf of Mexico generated a surge of 8.5 m (28 ft). The surge caused by Camille was 7.5 m (25 ft) high and it completely inundated Plaquemines Parish. The Mississippi River Gulf Outlet (MRGO), a dredged and artificially maintained shipping channel to the east of the river proper, was reportedly responsible for enhancing the Katrina storm surge that ultimately flooded New Orleans' Ninth Ward (NRC 2006). Chen et al. (2008) have hypothesized that if Katrina had tracked farther to the east and made landfall on the Alabama coast, the storm surge would been 4 m (13 ft) lower. As sea surface temperatures in the Gulf of Mexico increase in the decades ahead, it is likely that tropical cyclones will become more intense, but, there is no existing evidence that they will become more frequent.

13.5 Disappearing Wetlands

From uplands to the Gulf of Mexico, Louisiana's coastal vegetation types include (1) forests and freshwater swamps with cypress and tupelo gums, (2) floating marsh, (3) freshwater marsh, (4) intermediate marsh, (5) brackish marsh and (6) salt marsh. Figure 13.5 shows the distribution of these coastal vegetation types as they exist in 2017 (CPRA 2017). As pointed out earlier, the present rate of wetlands loss is around 41 km^2 (16 mi^2) per year and accelerating. The Louisiana Coastal Protection and Reclamation Authority (CPRA 2017) projects that by 2050, without reclamation, most of the wetlands will have been replaced by open water as portrayed in Fig. 13.6. Houma will be inundated and the narrow coastal barrier islands, such as Grand Isle, will be gone.

There are multiple contributors to Louisiana's wetlands loss. Inundation is the most obvious of these. As explained in Chap. 9, Sect. 9.6, the maximum rates of vertical accretion of salt marshes as well as deltaic surfaces in general are about 5 mm/year. Relative sea level rise rates in excess of these "tipping points" are likely to cause wetlands or deltaic lands to be replaced by open water (Morris et al. 2016; Turner et al. 2017). We pointed out earlier in this chapter that subsidence rates alone are causing inundation of as much as 18 mm/year and, when the modeled rates of future global sea level rise of between 8 and 16 mm/year are added to

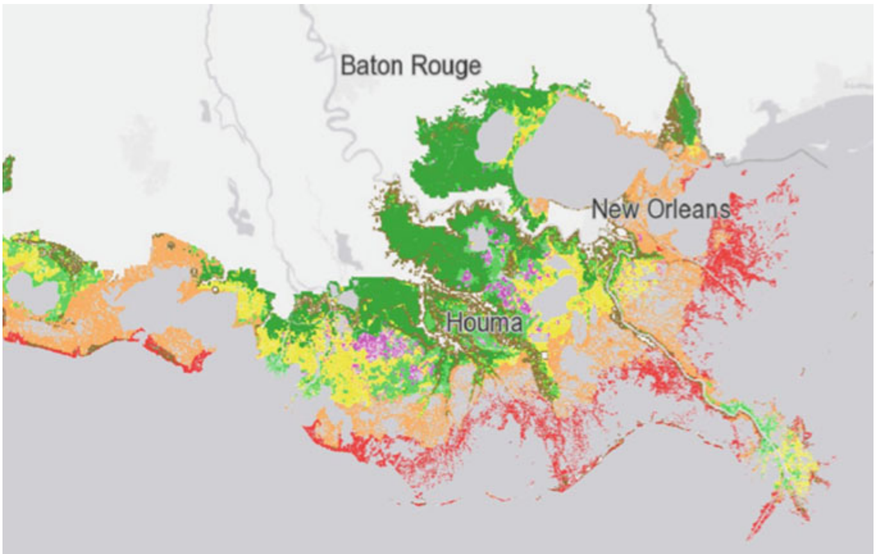

Fig. 13.5 Distribution of vegetation types in Coastal Louisiana in 2017. Figure from Louisiana Coastal Protection and Reclamation Authority (CPRA) on line Master Plan Data Viewer (2017) (https://cims.coastal.louisiana.gov/masterplan). *Key* Dark green—forest and swamp; purple—floating marsh; light green—freshwater marsh; yellow—intermediate marsh; orange—brackish marsh; red—salt marsh

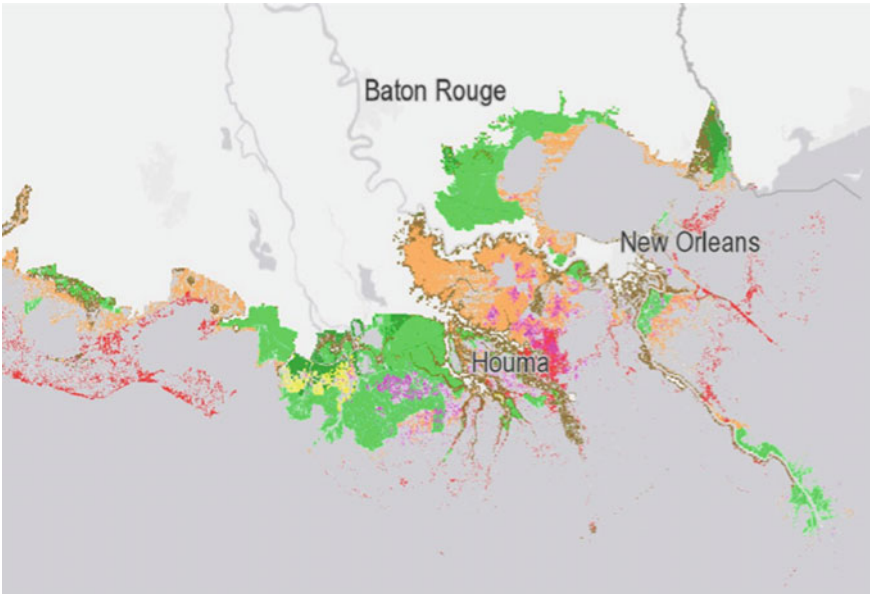

Fig. 13.6 CPRA projections for wetlands distribution in 2050 without reclamation

Fig. 13.7 Dredged access channels in Louisiana coastal wetlands. *Photo source* U.S. geological survey Louisiana coastal wetlands: a resource at risk. https://pubs.usgs.gov/fs/la-wetlands/

subsidence, the "tipping points" are exceeded by 5–6 fold. As open water bays grow in size, wave action becomes more energetic and progressively nibbles away at the marsh edges (Chap. 9, Fig. 9.3) creating a "positive feedback" loop. Landward intrusion of salt water causes dieback of freshwater swamps and marshes. Another important contributor to wetlands disappearance is the denial by levees and other engineering works of the supply of necessary sediments to nourish delta accretion. Finally, perhaps one of the most egregious and highly visible detriments to wetlands health is man-made destruction by the dredging of access canals and channels for oil and gas development (e.g. Dardis 2010; Fig. 13.7).

13.6 Engineering Impacts

Flood control levees on the Mississippi had been constructed by the latter part of the 19th Century and the impact of the levee system on the Mississippi Delta was clearly understood. E.L. Corthell wrote the following in 1897: "*The conditions are very different now from those existing prior to the construction of levees. There are at present no annual accretions of sedimentary matters from the periodical overflows of the river. These accretions formerly were a little more than equal to the annual subsidence of the lands… No doubt the great benefit to the present and two or three following generations accruing from a complete system of absolutely protective levees, excluding the waters entirely from the great areas of the lower delta country, far outweighs the disadvantages to future generations from the subsidence of the Gulf delta lands below the level of the sea and their gradual abandonment due to this cause.*" While this ominous prediction of land loss has come true, the levees of that time were unfortunately not designed to be high enough or strong enough to be effective. The Great Mississippi River Flood of 1927 motivated Congress to mandate the construction of levees high enough to keep the river completely contained in future such events (Barry 1998).

Today, the Mississippi's artificial levees serve the purpose for which they were intended: protecting lives and property along the course of the river. This protection has the added effect of increasing property values and supporting economic growth. However, these levees have also prevented overbank flows from supplying sediments to the deltaic plain and coastal wetlands and nutrients to farms and wetlands. Kesel (2003) compared the situation that existed in 1850 prior to levee construction to that of the late 20th century with levees and other controls. Notably, in 1850, Bayou Lafourch carried about 30% of the river's water and sediment load to Terrebonne and Barataria Bays to the west of the active Birdsfoot and overbank dispersal of sediment prevailed along the main and secondary channels. In contrast, by 1990, overbank flows had been eliminated and sediment was discharged directly into the Gulf of Mexico. In addition, river control structures upstream have completely cut off flows down Bayou Lafourch and directed 30% of the discharge down the Atchafalaya River to the west. Atchafalaya sediments discharged into

Atchafalaya Bay are at presently contributing the progradation of the Wax Lake Delta, the only actively accreting delta lobe on the Louisiana Coast (Xing 2015).

While protection of human health and wealth was a prime driver of engineering investment and construction, maintaining Mississippi River navigation for commerce and trade has always been close behind. Crucial to the navigability goal has been maintaining relatively deep-water channels from the river mouths to as far upstream within the river as ships may need travel. The three main mouths of the river in the active "birdsfoot" are Southwest Pass, South Pass and Pass a'lOutre. Pass a'lOutre the eastern most pass is not navigable by ships but the other two passes are. For ships entering from the east the Mississippi River Gulf Outlet was designed to provide a navigable short cut to New Orleans and the main channel of the Mississippi. To ensure navigable depths across the river mouth bars at the Southwest Pass and South Pass distributary mouths, the U.S. Army Corps of Engineers designed and constructed converging river mouth jetties. By concentrating the outflow, these jetties prevent rapid river mouth deposition and maintain depths sufficient to allow conventional shipping traffic to enter the passes. Unfortunately, they also cause the sediments that are needed to nourish the delta plain to be shunted into deep water. The third important type of impactful structures are oil and gas platforms and pipelines. These are extensive and are highly disruptive to wetlands ecology.

13.7 Adapting to Change: Complex Plans for the Future

The loss of wetlands, barrier islands and other lands in coastal Louisiana is severe and becoming worse. This has been known for several decades and, in 1990 Congress passed the federal Coastal Wetlands Planning Protection and Restoration Act (CWPPRA). With state and federal collaboration, an initial plan was developed in 1993. In 1998 the Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority (1998) prepared a long-range plan entitled *Coast 2050: Toward a Sustainable Coastal Louisiana.* In 2004, the U.S. Army Corps of Engineers published a report entitled *Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Study* (USACOE 2004). In late 2005, in the wake of Hurricanes Katrina and Rita, Louisiana restructured its Wetlands Conservation and Restoration Authority to form the Coastal Protection and Restoration Authority (CPRA). In 2017, CPRA released its most recent comprehensive master plan for a sustainable coast.

The National Research Council was asked to assess the USACOE LCA report and their report was published in 2006. In their assessment, NRC (2006) emphasized that returning coastal Louisiana to earlier conditions or even stopping future land loss on a state-wide scale is not really possible. What is more feasible, however, is to limit or slow future damage by targeting specific vulnerable or economically important localities for "triaged" protection or restoration. The NRC report specifically states that: "The challenge of slowing the loss of coastal wetlands and adjacent barrier islands and levees is unprecedented. The geographic extent of these wetlands and the range of natural and human forces that cause wetland degradation contribute to what would be one of the largest civil works projects in U. S. history" (NRC 2006, p. 17). They explain that the reasons for this challenge have much to do with the conflicts among nature, politics, regulations, economics and social traditions. Reconciliation among these conflicts is a challenge that must be, and surely can be, over come.

The CPRA has a plan and it is laid out in detail in the 2017 report. An interactive version can also be accessed on line at http://cims.coastal.louisiana.gov/masterplan/. Plans for future protections, and some reclamation, include a suite of site-specific strategies. One of these, involves a significant diversion of the lower Mississippi River to discharge sediment into Terrebonne and Barataria Bays to create a new delta lobe. Other strategies involve construction of new levees and elevating old ones as well as installation of floodgates. Non-structural strategies include flood mitigation by relieving or redirecting river flows during flood season, elevating and flood proofing commercial, public and residential structures, removing dangerous or environmentally harmful works, cessation of canal dredging, and, in some cases, relocating residents to upland areas. Several reclamation projects also rely on multiple structural and non-structural methodologies. One traditional approach is barrier island reclamation using dredged material or sediment pumped from offshore. Despite the ambitious plans and the likelihood of a large investment in implementing the envisioned projects, the prospects for the future of coastal Louisiana remain grim —the same human actions that have been taken to protect life and property have, in the long term, jeopardized them as well.

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