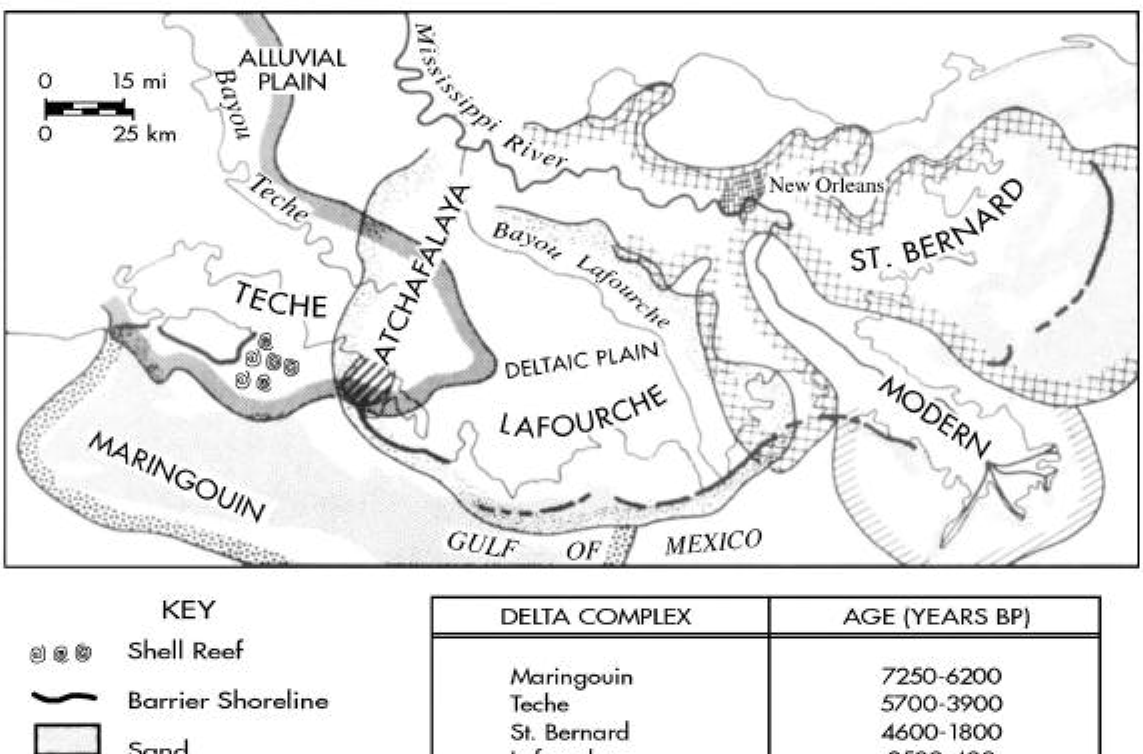
CHAPTER 2

CAUSES OF WETLAND LOSS

Over the last seven thousand years, the sediment washing down the Mississippi River created Louisiana's coastal wetlands. The river deposited sediment along its main channel and distributaries to the sea, creating land just above sea level that supported marsh and swamp vegetation. The delta building processes gradually lengthened the main channel's route to the sea. Every thousand years or so, the river switched to a shorter course, and built a new delta along this route (Coleman and Gagliano 1964; Frazier 1967). Figure 1 shows the delta "lobes" that have formed in the last seven thousand years; Figure 2 illustrates a generalized model of delta building and deterioration processes.

Once the river changed course, the wetlands along the old channel would gradually deteriorate and revert partially back to open water. The deltaic sediments have always tended to compact and sink while at the same time sea level has been slowly rising. Deprived of new sediment, the marshes would be unable to maintain their elevation above the surface of the water. As a result, the vegetation would die, and the marsh would deteriorate and "convert" to (be replaced by) open water. The change in river course would also reduce the availability of freshwater supplied to the wetlands, which would allow saltwater from the Gulf of Mexico to encroach inland, killing freshwater marshes and swamps, often converting them to open water as well.



DELTA COMPLEX	AGE (YEARS BP)
Maringouin	7250-6200
Teche	5700-3900
St. Bernard	4600-1800
Lafourche	3500-400
Modern	Active
Atchafalaya	Active

Figure 1. Sequence of Mississippi River delta lobe formation (modified from Frazier 1967).

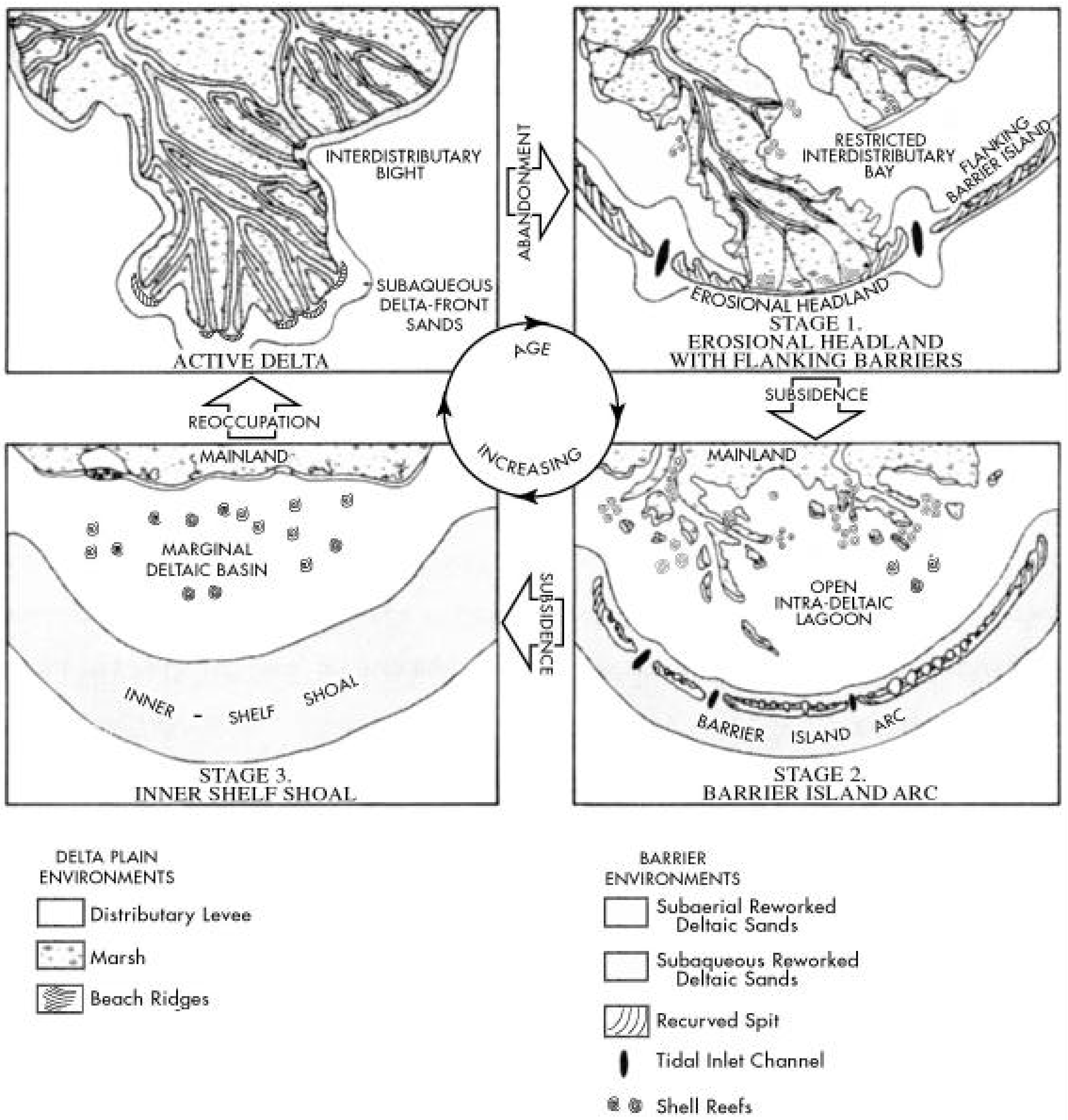


Figure 2. Cycle of delta growth and decay (after Penland and Boyd 1961).

Coastal Louisiana has always experienced natural wetland loss in the abandoned delta after the river changed course. Until recently, however, the loss was always more than offset by creation of wetlands in the new delta. Seven thousand years ago Louisiana's Gulf of Mexico shoreline was along a line corresponding to the present locations of Slidell, Baton Rouge, Lafayette, and Lake Charles; today it is fifty to one hundred miles south of that location.

In the last century, human activities have disrupted the natural delta-building cycle. Levees along the Mississippi River built for flood protection prevent the river from overflowing its banks and conveying freshwater and sediment to the wetlands during annual floods. Navigation channels and projects that artificially maintain the river's banks speed the river's flow, preventing sediment from settling out. Many distributaries have been closed. As a result, the sediment, freshwater, and nutrients carried by the Mississippi River now wash out into the deep waters of the Gulf of Mexico, rather than spreading out to nourish and build Louisiana's coastal wetlands.

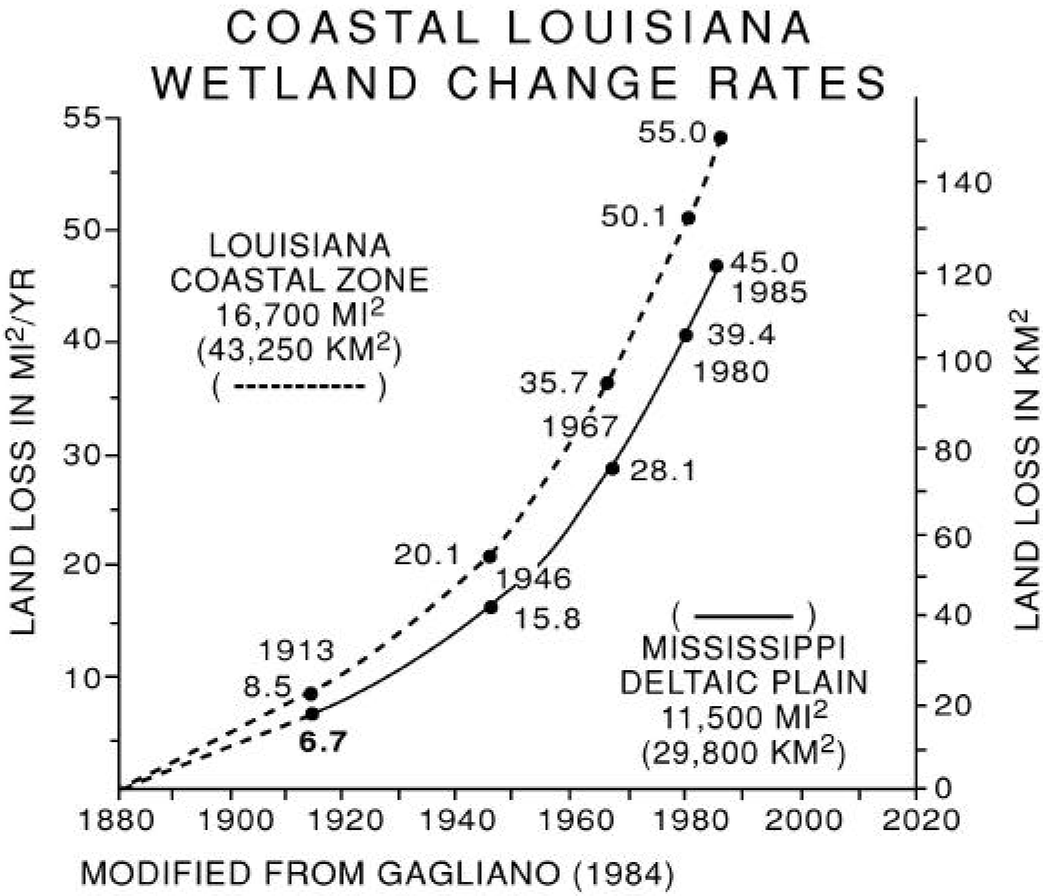


Figure 3. Rates of wetland loss in the Louisiana coastal zone compared with loss in Mississippi Deltaic Plain.

Human activities have also prevented the Mississippi from changing its course to the Atchafalaya River. Although this river does capture 30 percent of the Mississippi River's flow and is creating a small delta at its mouth, without the upstream control structure built by the U.S. Army Corps of Engineers, the majority of the river's flow would reach the Atchafalaya delta and a far larger amount of wetlands would be created.

Canals dredged through the marsh have also contributed to the loss of wetlands in a number of ways. In some parts of Louisiana, the direct losses from dredging the canals themselves are quite large. Waves from boats traversing the canals further erode the marsh. The canals also provide a conduit for saltwater to advance rapidly inland into cypress swamps and freshwater marshes that cannot tolerate saltwater, particularly where the flow of freshwater from the river to the wetlands has been blocked. Finally, spoil banks from dredging canals interrupt the flow of water and nutrients. Other activities also contribute to wetland loss, including draining and filling for development, agriculture, sanitation, and navigation.

As a result of these human factors, the historic expansion of the Mississippi Delta has been reversed. Coastal residents and some scientists first noticed marsh deterioration and shoreline erosion more than fifty years ago (e.g., Russell 1936). However, the rate of land loss was not established until Gagliano and van Beek (1970) estimated that Louisiana was losing 16.5 square miles per year. Wicker (1980) later showed that the deltaic plain lost 39 square miles per year between 1955 and 1978. Gagliano et al. (1981) concluded that the rate of wetland loss has been increasing geometrically over the last century. As Figure 3 shows, the rate of wetland loss in 1985 for the deltaic plain alone is 45 square miles per year. The

Chenier Plain in southwestern Louisiana is losing an additional 10 square miles per year (Gosselink et al. 1979), bringing the total land loss within the Louisiana coastal zone to approximately 55 square miles per year (nearly 100 acres per day). Figure 4 illustrates average rates of wetland loss for various portions of coastal Louisiana. Figure 5 illustrates the land loss that has taken place at the mouth of the Mississippi River, where the rate of loss is among the highest.

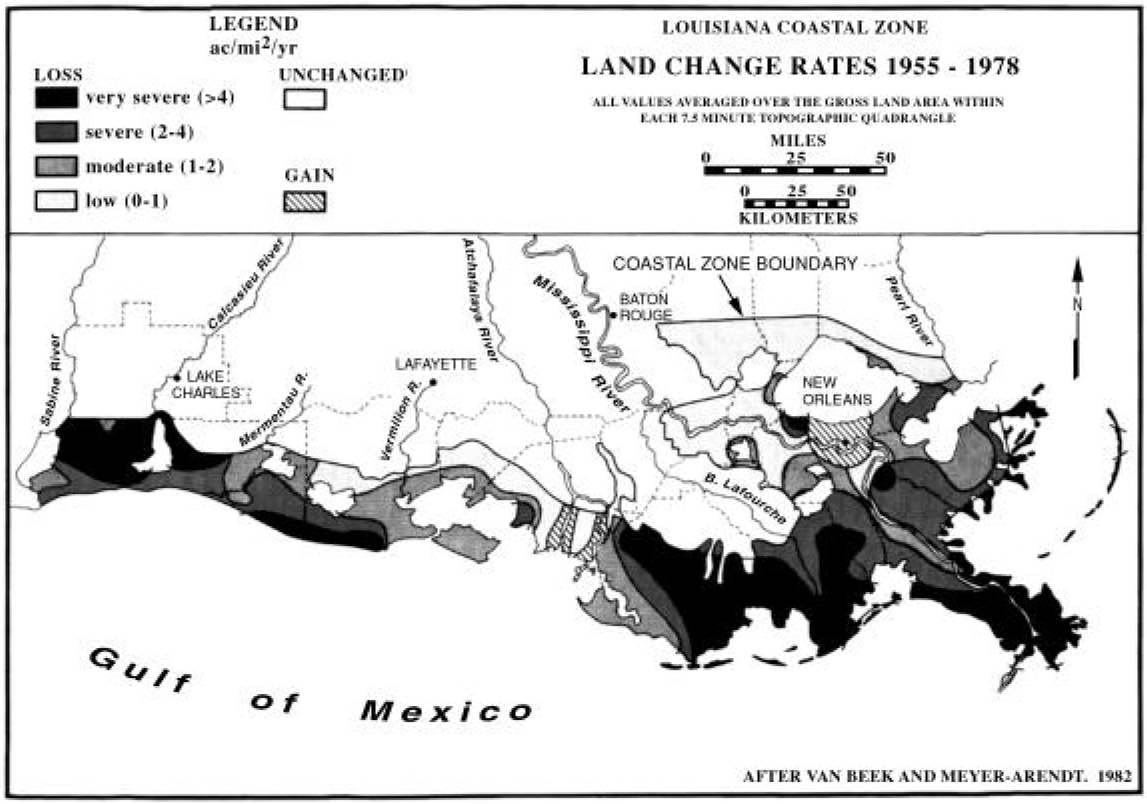


Figure 4. Land change rates in the Louisiana coastal zone, 1955 – 1978.

Recent studies by the U.S. National Academy of Sciences (Charney 1979; Smagorinsky 1982; Nierenberg et al. 1983) and international meetings of atmospheric scientists (e.g., UNEP/WMO/ICSU 1985) suggest that the rate of wetland loss may further accelerate in the future. Increasing concentrations of carbon dioxide and other gases are expected to cause a global warming that could raise sea level one meter (three feet) or more in the next century (Revelle 1983; Hoffman et al. 1983 and 1986; Meier et al. 1985). Such a rise would represent a major acceleration of the historical trend of 10 to 15 centimeters (4 to 6 inches) per century, and could eventually double or triple the rate of wetland loss. Figures 6a and 6b illustrate projections of the state's shoreline for current sea level trends and a 55-centimeter rise by the year 2033.

Many of the panel members initially recommended that this report place less emphasis on the issue of accelerated sea level rise. Not because it is not a serious possibility, but because a one-meter rise could have implications so profound as to cast doubt upon the wisdom of undertaking major efforts to protect Louisiana's wetlands, and might thereby lead to a delay in several pending projects. Moreover, the predictions of future sea level rise are still very uncertain. However, the panel concluded that the possibility of an accelerated rise in sea level implies that these projects would be even more essential to buy time, while a long-range strategy is formulated.

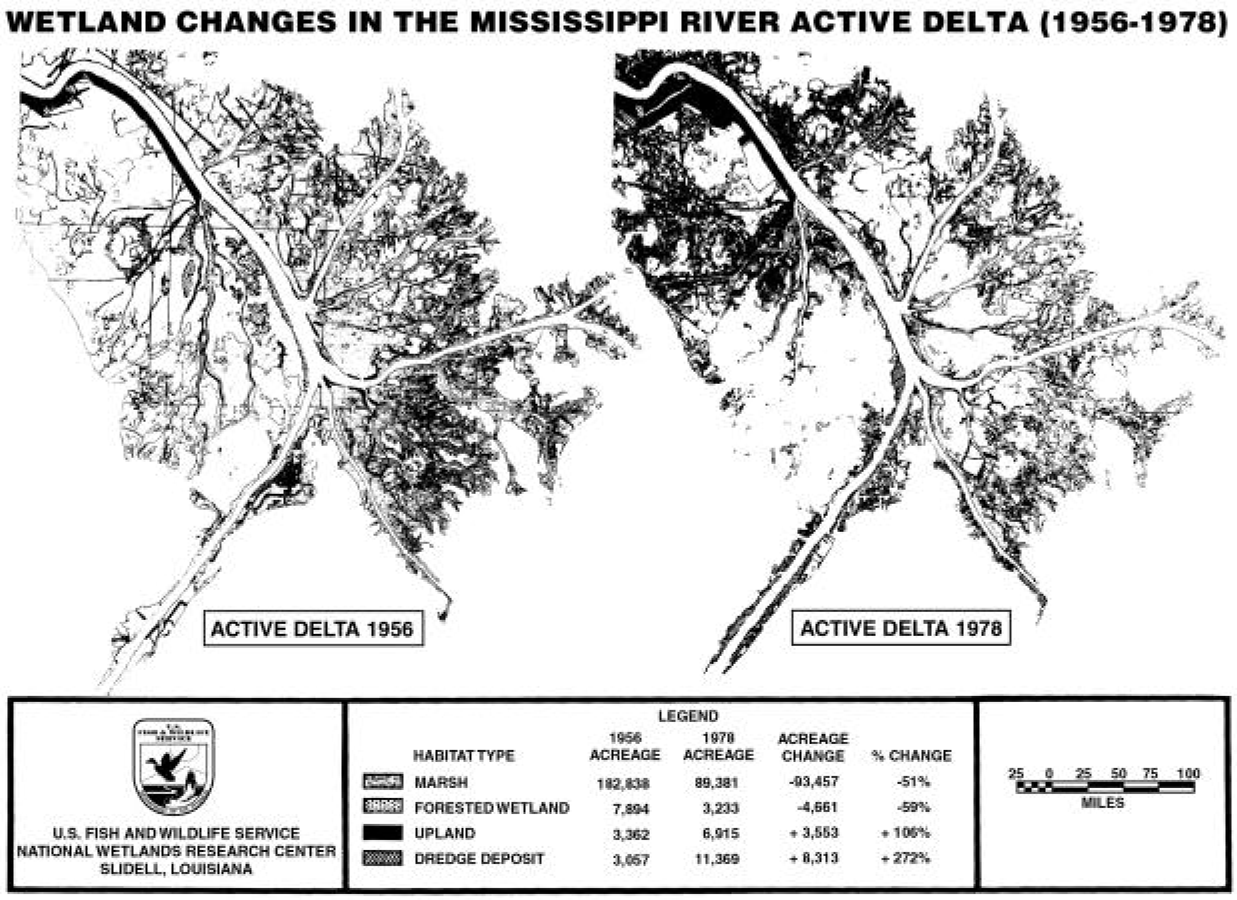


Figure 5. Illustration of wetland loss at the mouth of the Mississippi river.

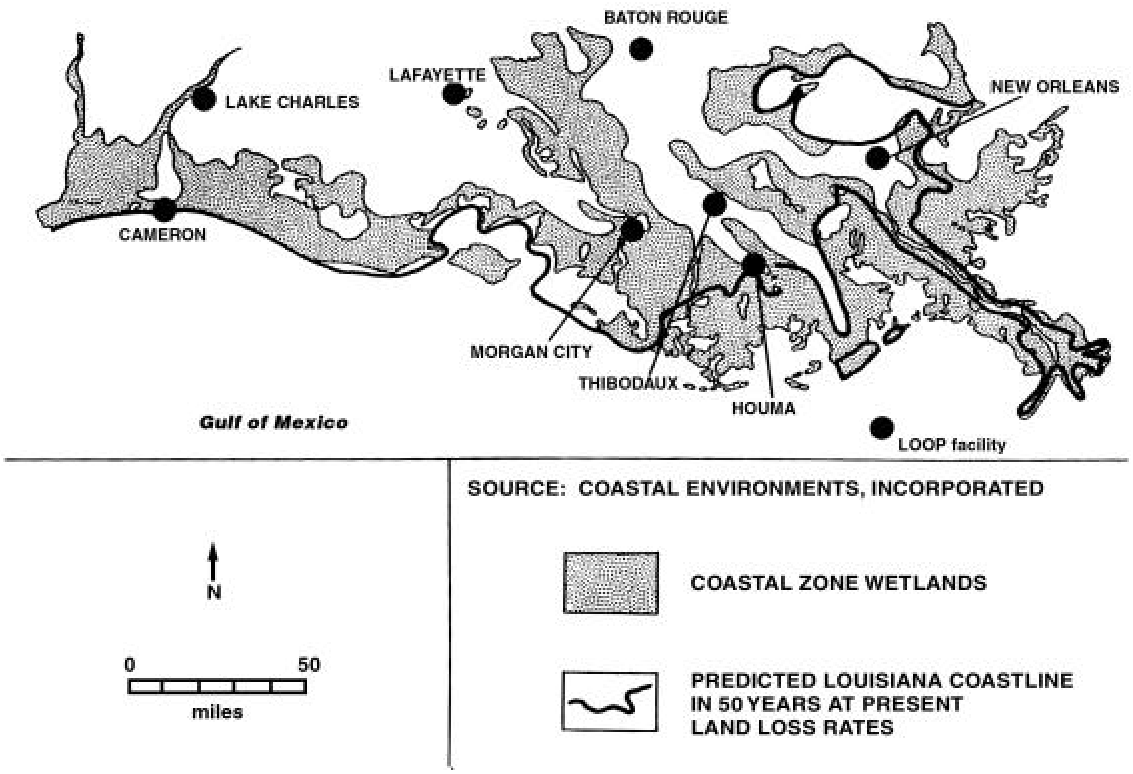


Figure 6a. Louisiana shoreline in the Year 2030.

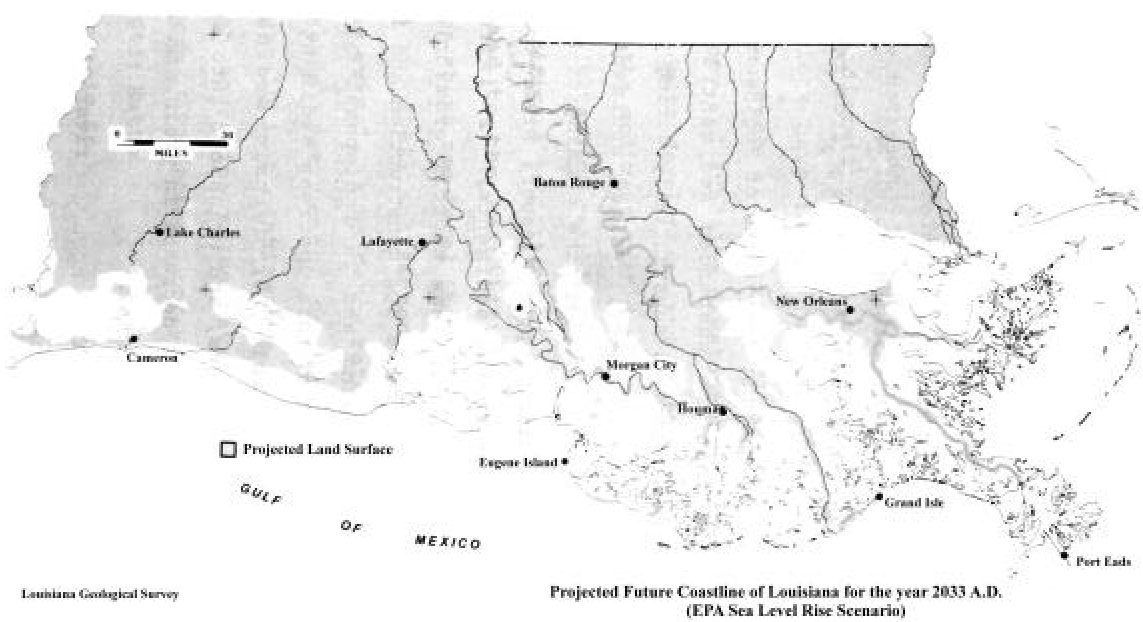


Figure 6b. Projected future coastline of Louisiana (after Ramsey and Moslow 1987) for the Year 2033 A.D. Given a rise in sea level of 54.9 cm as predicted in the high scenario (from Hoffman et al. 1983).

The remainder of this chapter discusses the factors causing land loss in more detail.

(1) Sediment Deficit

A major cause of wetland loss in Louisiana involves the reduction in sediment available to maintain the wetlands above sea level. This reduction can be attributed to two causes: less sediment flowing down the Mississippi River and confinement of the river in a manner that prevents sediment from reaching the wetlands.

Recent studies by the U.S. Army Corps of Engineers (Keown et al. 1980) indicate that the suspended sediment load of the Mississippi River has decreased substantially during the last 20 years, especially the larger-grain-sized sediments (sands). Causes of these changes include: (1) the damming of Mississippi River tributaries (especially upper Missouri River tributaries, sources of most of the coarse sediments); (2) improved soil conservation practices (i.e., less topsoil erosion); (3) the mining of pointbar (river) sands for construction and industrial usage; and (4) the dredging and land disposal of riverine sediments. The net effect of this upstream sediment use is to reduce the amount available for deltaic sedimentation, nourishment of barrier beaches, and transport into marshes by floods and tidal currents. The decrease in grain sizes has also reduced the land-building potential.

Although the sediment washing down the river has decreased, there is some doubt regarding the extent to which this reduction should be implicated as a source of wetland loss. The sediment loading that prevailed during the first half of the twentieth century may have been unusually high, due to altered farming practices and the dust bowl of the 1930s. However, there is little doubt that confinement of the Mississippi River resulting from artificial levee construction along practically its entire length has played an important role in the disintegration of Louisiana's wetlands. Levees and control structures restrict the flow into distributary channels and crevasses. These human modifications have interfered with natural delta building processes, such as overbank flooding and sedimentation, distributary and subdelta development, and broader, long-term cycles of delta development and abandonment (Frazier 1967). As a result, the sediment that does wash down the river is funneled offshore, instead of reaching the wetlands.

A significant proportion of Louisiana's land loss is directly attributed to the inability of the marsh to maintain its elevation above sea level (Baumann and DeLaune 1982; DeLaune et al. 1978 and 1983; and Hatton et al. 1983). Between 1954 and 1963, for example, subsidence rates were about 1.2 centimeters (0.49 inches) per year. Streamside marshes have accreted approximately 1.32 centimeters (0.52 inches) per year, while backmarsh accretion rates have been only approximately 0.72 centimeters (0.28 inches) per year (DeLaune et al. 1978; DeLaune et al. 1983; Hatton et al. 1983). Thus, only streamside marshes have been able to keep pace with subsidence and sea level rise. Away from streamside locations, where tidally transported mineral sediments are deposited, the marshes are rapidly eroding because of this sediment deficit.

Different marsh types show considerable variability. Hatton et al. (1983) found that intermediate and brackish marshes(0.1-1.0 percent salinity) exhibited the highest rates of conversion to open water. While exhibiting higher conversion rates, freshwater marshes have often converted to more saline marsh rather than open water.

The interference with distributary and subdelta formation processes has not only altered sedimentation patterns but delta building mechanisms in general. By maintaining the course of the Mississippi River within its present channel with various engineering controls, large-scale "delta-switching" has been prevented. During the 20th century, an increasing proportion of Mississippi River water has been flowing down the Atchafalaya River (a distributary of the Mississippi), which could become the new main channel. To prevent this from happening, the Flood Control Act of 1954 directed the U.S. Army Corps of Engineers to regulate Atchafalaya discharge to approximately 30 percent of total Mississippi River discharge by constructing the Old River Control Structure near Simmesport, Louisiana (Figure 7). The nearly completed Old River Auxiliary Structure will further reduce the possibility of a natural diversion. In spite of flow restrictions, Atchafalaya River sedimentation has filled its inland depressions in the Atchafalaya Basin and is now actively building a delta out into Atchafalaya Bay. Although this delta is only about 10 square miles today, Wells et al. (1983) project that it will grow to 80 square miles by 2030. The active sedimentation there represents the only significant wetland creation in Louisiana today.

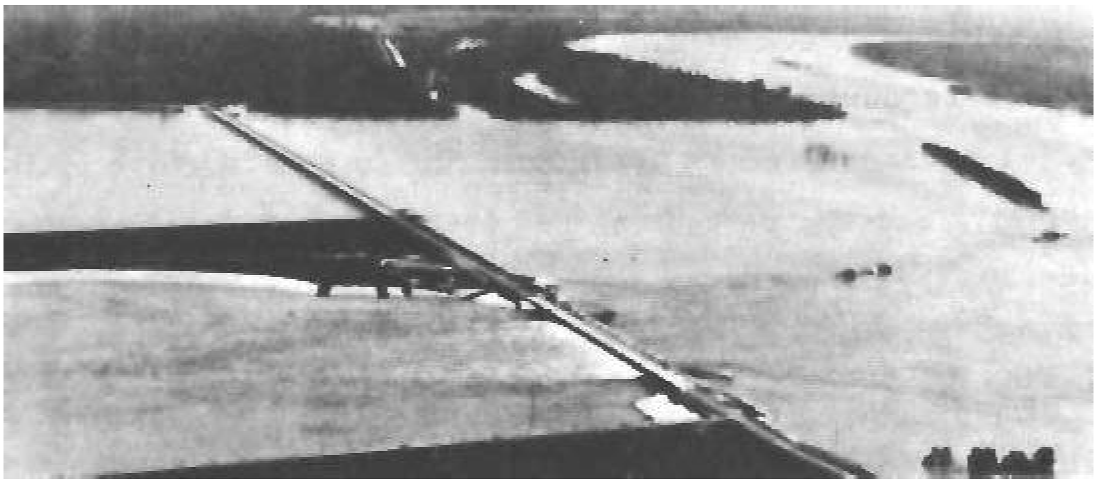


Figure 7. Old River Control Structure near Simmesport, Louisiana.

(2) Canals

Canals currently comprise about 2.5 percent of the total coastal surface area in Louisiana (Craig et al. 1980; Turner et al. 1982), and the percentage has been accelerating through time. Historically, canals have been dug for drainage and access. Today the greatest share of canalization is attributed to the oil and gas industry (Figure 8). In 1984, 70 to 80 percent of the coastal management permits issued for canals were for oil and gas activities. The primary reasons for the myriad of canals in the Louisiana coastal zone include navigation, pipeline routes, and access to drilling sites.

Although dredging canals has only directly converted 2.5 percent of the wetlands to open water, their impact is much greater. Spoil banks composed of the material dredged from the canals tend to smother adjacent marshes, converting wetlands to uplands, often interrupting natural hydrologic processes, and blocking the distribution of sediment. Canals oriented perpendicular to water flow tend to impound water and reduce sediment availability, and ponding of water can drown a marsh. Canals parallel to water flow tend to lessen freshwater retention time and allow greater inland penetration of saltwater. Turner et al. (1982) estimate that as much as 90 percent of Louisiana's land loss can be attributed to canals.

(3) Reclamation

Reclamation of water or wetlands--via fill, dredge and fill, or drainage--is usually undertaken for purposes of creating dry land that can be used for residential (see Figure 9), industrial, or agricultural purposes. Consequently, the areas in which reclamation poses the greatest threats are near large urban areas (notably New Orleans) and along the backswamps that fringe populated natural levees.

At the turn of the century, many agricultural ventures took place in the Louisiana wetlands, later resulting in the numerous rectangular water bodies that now dot the coastal landscape due to failed levees and inundated fields. Urban and agricultural reclamation of backswamp wetlands continues to have substantial impacts.

Figure 8. Canals dug in Louisiana's coastal marshes for oil and gas drilling and production operations.

Figure 9. Wetlands dredged and filled for residential development along the north shore of Lake Pontchartrain.

(4) Wave Erosion

A. Gulf Shoreline Erosion. Rates of shoreline erosion appear to have increased during the last several decades, due to human activities (e.g., jetty construction, reef removal, sand mining), indirect human impacts (e.g., reduction in available sediment, accelerated subsidence), sea level rise, and increased frequency of hurricane landfall (Morgan & Morgan 1983; Penland and Boyd 1982; Penland and Suter 1984; Penland et al. 1985; van Beek and Meyer-Arendt 1982). Rates of shoreline erosion exceed ten meters (thirty-three feet) per year, along much of the barrier coast, in both the deltaic plain and the chenier plain. (See Figure 10.) These high rates threaten established development along the coast. (They no longer threaten the base line from which the three-mile offshore state/federal boundary is measured, which has been fixed by Congress.) The rapid disintegration of the barrier islands and beaches also threatens Louisiana's first line of defense against incoming stormsurges. (See Figure 11.) If the beaches and marshes disappear, cities such as New Orleans, Houma, and Morgan City will be subjected to higher storm surges and direct wave attack during severe storms.

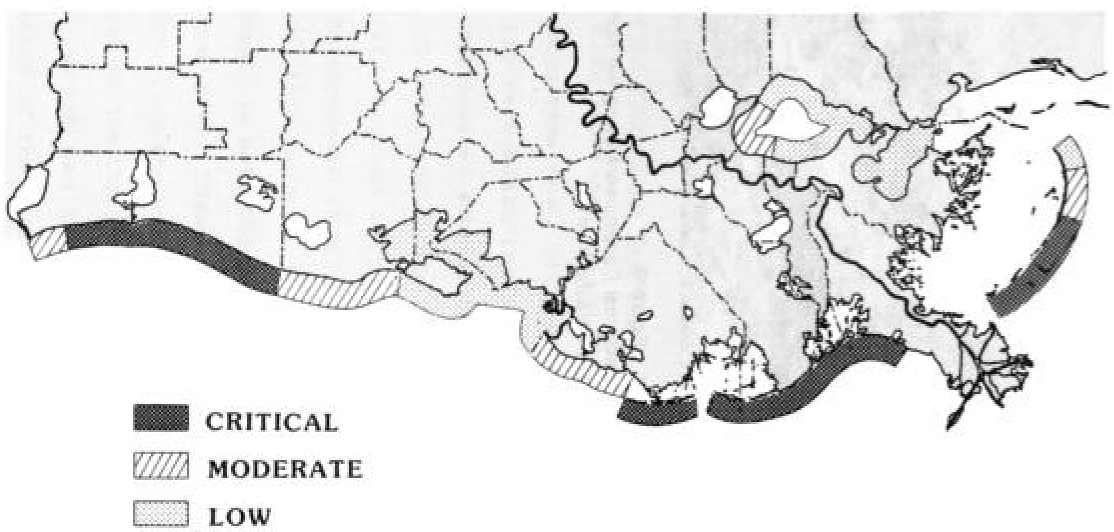


Figure 10. Severity of Louisiana shoreline and barrier island erosion.

<u>B. Lake/Bayshore Erosion.</u> The physical process of waves interacting with the shoreline also occurs within estuaries and is an important factor, especially along the shores of larger lakes or bays.

Unlike the Gulf shoreline where incoming waves have been generated at distant locations, wave generation within the estuaries is localized and depends primarily upon prevailing winds and boat wakes. Wind-generated wave energy is a function of wind speed, duration, fetch (distance across water body), and depth. Theoretically, the highest bayshore erosion rates should occur in the largest bays, other factors remaining equal. Bayshores facing prevailing winds (NW during winter, S-SE during summer) appear to be the most vulnerable. One study of bayshore erosion, however, determined that factors varied from location to location (Adams et al. 1978).

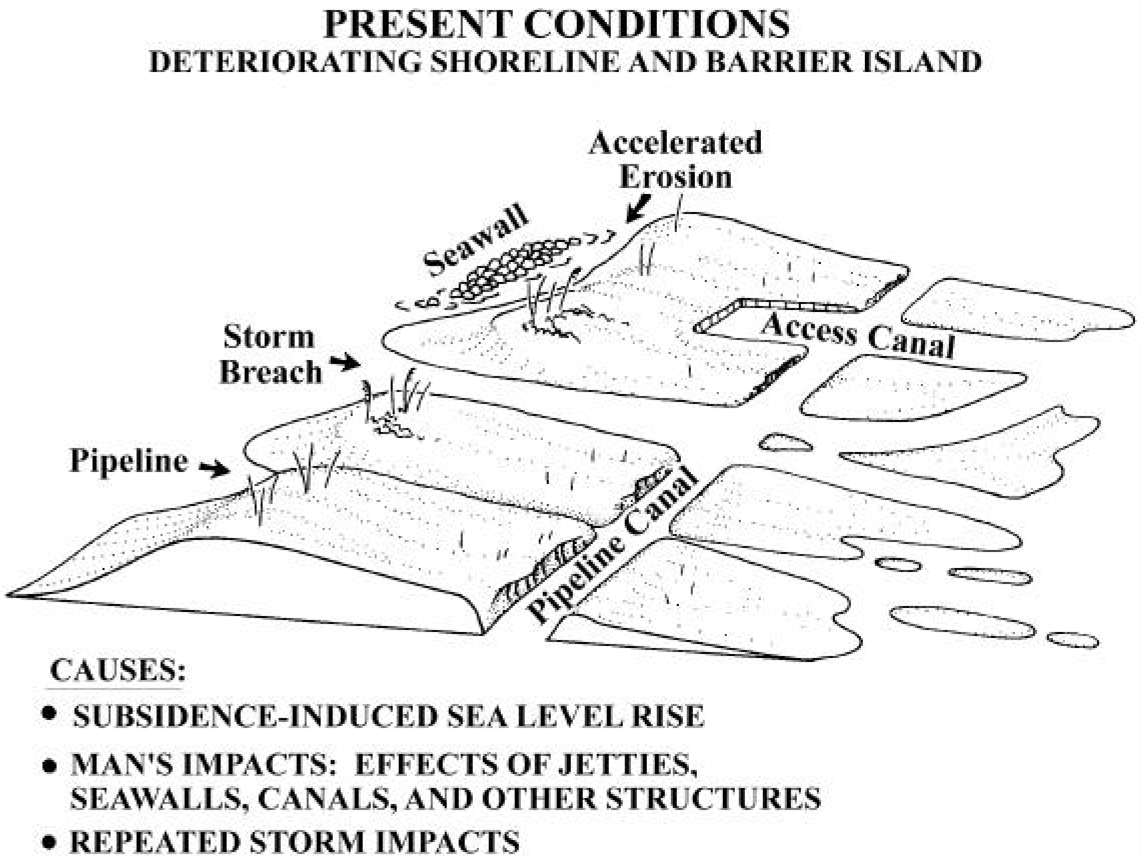


Figure 11. Existing conditions on many of Louisiana's deteriorating shorelines and barrier islands.

Figure 12. Rapid widening of canals occurs as a result of boat wake and tidal erosion along the banks of major navigation channels.

C. Canal/Bayou Erosion. Canals and natural waterways are widening as a result of bank erosion, but the causal factors are man-made and thus much more recent and somewhat different from those in the previous two cases. (See Figure 12.) Wind and fetch-related factors are less important, while boat wakes and tidal hydraulic energy (i.e., the ebb and flow of the tides) are more important. Several studies have documented canal widening from ship traffic (e.g., Howard et al. 1984; Johnson and Gosselink 1982; Turner et al. 1982; Doiron and Whitehurst 1974), and an excellent schematic of bank erosion is presented by Howard et al. (1984). Tidal hydraulic energy in Louisiana estuaries increases in response to subsidence (i.e., increased tidal prism) and tidal inlet widening, both attributed to a combination of subsidence and barrier island erosion. Although few hard data are available, it is likely that boat wake erosion in canals and bayous is more destructive to adjacent marshes than tidal erosion.

(5) Subsidence

Because Louisiana's coastal zone is extremely flat, even a slow rate of land subsidence can result in large-scale disappearance of marshlands if no additional sediment is provided to the system. (See Figures 13 and 14.) The subsidence that occurs in Louisiana can be divided into two general categories: tectonic subsidence and consolidation/compaction (modified from Adams et al. 1976 and Mossa 1980).

Figure 13. Marsh tract that has been able to keep pace with subsidence.

Tectonic subsidence refers to the large-scale downward geologic displacement caused by sedimentary loading and associated settlement processes (Adams et al. 1976). This type of subsidence is directly linked to the Mississippi River system,which built Louisiana's deltaic plain during the last seven thousand years (Coleman and Gagliano 1964; Boesch et al. 1983). Beneath the present active delta,for example, as much as 1,000 feet of sediments have accumulated, and land subsidence rates have been estimated at 1.5 to 3 meters (5 to 10 feet) per century (Russell 1936). Away from the active delta, the rate of sedimentary loading and associated subsidence decreases. Although present subsidence rates in the lower deltaic plain are estimated at approximately ten millimeters per year (three feet per century) by Nummedal (1983), longer-term rates have been estimated between 1 and 5 millimeters per year (4 to 22 inches per century) (Boesch et al. 1983).

The consolidation/compaction aspect of subsidence is attributed to a variety of causes including overlying weight, subsurface withdrawal, and dewatering.

Figure 14. More typical view of coastal wetlands that are not receiving enough new sediment to offset the effects of subsidence and are disappearing below the water surface.

A. Overlying Weight. Examples include physical features, such as natural levees, man-made levees, buildings, spoil mounds, and even marsh-buggy traffic. The net consequence of this overlying weight is localized surface sinking as soils are compressed. In the case of natural levees, adjacent marsh soils are also often compressed to the point where waterfilled "levee-flank depressions" result (Russell 1936). Although soil compression from marsh buggies may be temporary, rebounding often does not occur, and the ruts evolve into permanent water scars.

B. Subsurface Withdrawal. The withdrawal of oil, gas, and groundwater from subsurface sedimentary strata results in subsidence, which can manifest itself in the form of localized surface subsidence (Martin and Serdengecti 1984). Based on studies in Texas and California, it is generally agreed that withdrawal from strata less than approximately 10,000 feet below the surface can cause the land surface to subside (Boesch et al. 1983; van Beek and Meyer-Arendt 1982). Although Martin & Serdengecti (1984) estimate that normally pressurized oil and gas reservoirs in Louisiana should have a maximum equilibrium subsidence of only 2 centimeters (0.8 inches), the high localized land loss rates near major hydrocarbon reservoirs (e.g., Hackberry Dome, Venice Dome, Garden Island Dome) led Adams et al. (1978) to suspect higher compaction rates.

C. Dewatering. The water table is essentially at or near the surface in a wetland environment. When it is lowered because of drainage activities, the dewatered upper soils are subjected to processes of biochemical oxidation, soil shrinkage, and wind erosion (Mossa 1980). Although "natural" factors, such as marsh burning, have been cited as causing soils to dry out and subside (Adams et al. 1976), it is primarily human efforts related to urban expansion, agricultural drainage and reclamation, and flood control that have led to widespread localized surface subsidence. In terms of land loss, the most severe environmental impacts have resulted from the failed agricultural reclamation projects that proliferated in the early decades of this century (Gagliano 1973). After these large areas of former wetlands subsided because of dewatering associated with drainage, the subsequent failure of protection levees caused rapid inundation of the entire tracts.

(6) Sea Level Rise

Because of the difficulty of separating the effects of subsidence and sea level rise during any analysis of relative changes between land and water levels, many researchers have packaged the two factors together for convenience under headings such as "relative subsidence" or "relative sea level rise." Because surface processes are a function of the net effect of the two causal factors, their separation is largely academic.

Based on various studies of tidalgauges throughout the world, commonly accepted rates of present eustatic (global) sea levelriserange from 1.0 to 1.5 millimeters per year (4 to 6 inches per century) (Gornitz et al. 1982; Barnett 1984). Tidal gauges along the coast of Louisiana indicate that the rate of relative sea level rise is 9 to 13 millimeters per year (3 to 4 feet per century) (Baumann and DeLaune 1982; Ramsey et al. 1985). Thus, global sea level rise accounts for about 10-15 percent of relative sea level rise along the Louisiana coast.

Recent developments suggest that sea level could become more important in the future. Three panels of the U.S. National Academy of Sciences, and international conferences of climatologists and oceanographers have concluded that increasing concentrations of carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, and other gases will warm the planet several degrees in the next century (Charney et al. 1979; Smagorinsky et al. 1982; Nierenberg et al. 1983; UNEP/WMO/ICSU 1985). Such a warming could cause sea level to rise by expanding ocean water, melting mountain glaciers, and eventually causing polar glaciers to melt or slide into the oceans.

In 1983, two independent reports published estimates of future sea level rise. The National Academy of Sciences Climate Research Board estimated a 70-cm rise by 2080, assuming that the possible disintegration of Antarctic glaciers does not begin by that date (Revelle 1983). The Environmental Protection Agency developed a variety of scenarios to incorporate uncertainties regarding future emissions on "greenhouse gases", the resulting impact on climate, oceanic heat absorption, and the response of glaciers to the warming, and estimated that a global rise in sea level of 26 to 39 centimeters by 2025 and 91 to 137 centimeters by 2075 is most likely (Hoffman et al. 1983). A 1985 report by the National Academy of Sciences Polar Research Board for the first time provided models of the response of specific ice fields to the projected global warming. Meier (1984) and Bindschadler (1985) estimated that alpine and Greenland glaciers, respectively, could raise the sea 10 to 30 centimeters by 2100. Thomas (1985) estimated that the contribution of Antarctica by 2100 is most likely to be about 30 cm, but that a contribution of 1 to 2 meters is possible. The panel did not revise Revelle's estimate of thermal expansion. Hoffman et al. (1986) revised their earlier projections in light of this new information, estimating the rise by 2025 to be between 10 and 21 centimeters, and 36 to 191 centimeters by 2075.

Table 1 summarizes available estimates of global sea level rise and relative sea level rise along the coast of Louisiana implied by current subsidence. Current trends would result in a 90-centimeter (3-foot) relative rise by 2085; the most conservative scenario of future sea level rise implies that such a rise will take place by 2060; but a 90-cm rise by 2040 cannot be ruled out. The current rate of relative sea level rise (1 cm/year) could double by 2030 and perhaps triple by the end of the next century.

(7) Saltwater Intrusion

Saltwater intrusion is technically not an active process but a passive response to the aforementioned processes. Canals and the reduction of freshwater supplied to the wetlands caused by levees and channelization have been the primary causes of increased salinity levels in the wetlands. Land subsidence, sea level rise, and barrier island erosion also cause saltwater ntrusion. The inland encroachment of higher salinities, evidenced especially by the changing distribution of oyster-growing areas (Van Sickle et al.

1976) is held responsible for a number of environmental impacts. For example, the optimal oyster-growing areas in each basin are shifting inland closer to sources of freshwater but also closer to sources of urban runoff, which may have high concentrations of contaminants. Although the more saline marsh types may be less valuable to furbearing animals and birds, they can be more important as estuarine nursery grounds. Some of the most severe impacts of saltwater intrusion include the destruction of cypress forests (Figure 15) and floating fresh marsh (flotant), neither of which can survive in brackish or saline water. Although fresh and brackish marshes are often replaced by brackish and salt marshes, respectively, cypress swamps frequently convert to open water instead of being replaced by more saline vegetation.

Table 1

Estimates of Future Worldwide Sea Level Rise
(centimeters above 1980 level)

	2000	2025	2050	2075	2080	2100
<u>Global Sea Level Rise</u>						
Current Trends	2.4	5.4	8.4	11	12	14
Revelle (1983)					70	
Meier et al. (1985)						50-200*
Hoffman et al. (1983)						
Low	4.8	13	23	38	-	56
mid-low	8.8	26	53	91	-	144
mid-high	13.2	39	79	137	-	217
High	17.1	55	117	212	-	368
Hoffman et al. (1986)						
Low	3.5	10	20	36	44	57
High	5.5	21	55	191	258	358
<u>Louisiana Relative Sea Level Rise</u>** (Wordwide sea level rise plus sibsidence)						
Current Trends	22	50	78	106	112	134
Revelle (1983)					170	
Meier et al. (1985)						170-320
Hoffman et al. (1983)						
Low	25	58	93	133	-	176
mid-low	29	71	123	186	-	264
mid-high	33	84	149	232	-	337
High	37	100	187	307	-	488
Hoffman et al. (1986)						
Low	24	50	90	111	144	177
High	26	61	125	286	358	478

* Assuming Revelle's model for thermal expansion, which implies 40 cm by 2100.

** Assuming subsidence of 1 cm per year.

Figure 15. Destruction of a former cypress swamp by saltwater intrusion.