WETLAND CHANGES IN COASTAL MISSISSIPPI, 1950s to 1992*

by

Klaus J. Meyer-Arendt, Ph.D.

and

Stephen M. Oivanki and Barbara Yassin

Introduction

In 1992, a research project documenting recent changes in land use/land cover categories of the mainland portion of the Mississippi coastal zone was initiated. This research was a collaborative effort by the Office of Geology, Mississippi Department of Environmental Quality and the Department of Geosciences, Mississippi State University as part of the Mississippi Coastal Geology and Regional Marine Study funded by the U.S. Geological Survey in the years 1990-1994. The purposes of the study were: a) to provide cartographic and quantitative baseline data from which land loss—particularly wetland loss—could be identified, b) to document temporal trends in land cover changes, especially in Mississippi's coastal wetlands, and c) to provide a starting point for further scientific research into the geomorphic processes that affected or were affected by alterations in Mississippi's wetlands and adjacent coastal uplands.

Geologic foundations of wetlands

Wetlands may be defined by either geologic or biotic parameters, and in public usage it is usually the latter that receives most attention. Geologically, wetlands are a transitional category between dry land and open water. Soil-forming processes characterize the sedimentary substrate in wetland environments in spite of regular—and often lengthy—periods of inundation. Wetlands play a major role in sediment budgets, especially in terms of interrelationships between terrestrial and aquatic environments. Because of the unique geomorphic setting of wetlands, a similarly unique set of vegetation tends to colonize it. And because it is easier to identify and map the visible vegetation than the soil or the substrate, the term "wetlands" has become associated with the biotic instead of the geologic.

The geologic importance of wetlands is increasingly being recognized, especially relative to hydrologic and sediment flux processes in fluvial and coastal environments. The U.S. Army Corps of Engineers presently uses a hydrogeomorphic classification of wetlands to assess functions and assign values to the variety of wetlands found in the United States and its possessions (Brinson, 1993).

Concerns over wetland loss

Wetlands are among the most valuable ecosystems on earth. Found at the landwater ecotone, and defined in part on the basis of at least seasonal inundation of standing water, wetlands play major roles in cleansing polluted water, absorbing storm wave energy, and recharging groundwater.
Wetlands are among the greatest biomass-producing environments on earth (Mitsch and Gosselink, 1986). Their increasing recreational and commercial value in terms of fish and wildlife production is recognized by scientists, policymakers, and the general public.

Wetlands have been shrinking in recent years, and both human and natural processes are being blamed. Although this loss of wetlands in the United States has been noted since the turn of the century, especially by duck hunters, not until a U.S. Fish and Wildlife (USFWS) report was released in 1980 was the overall severity recognized (Wicker, 1980). In this study, habitat maps of the mid-1950s were compared with similar maps of the late 1980s for a region encompassing southeast Louisiana and coastal Mississippi (Wicker et al., 1980). Preliminary interpretation of the data indicated that southeast Louisiana was losing wetlands at an incredibly high rate of about 40 square miles per year (mi²/yr) (Gagliano et al., 1981). Many follow-up studies have since been conducted, and both human-induced and natural processes have been blamed for wetland losses throughout the U.S. (Gosselink and Baumann, 1980; Meyer-Arendt, 1987; Mitsch and Gosselink, 1986; Tiner, 1984; Turner and Cahoon, 1987; and Williams, 1990). In view of recent evidence of sea level rise, perhaps induced by a trend of overall global warming, concerns about corollary accelerated wetland losses have increased (Burrage, 1991; Day and Templet, 1989; Hoffman et al., 1983; Meyer-Arendt, 1990; Orvos, 1991; and Titus, 1988).

Despite national (and international) concern over wetland loss, little attention has been paid to the coastal wetlands of Mississippi. It was the aim of this project to analyze the Mississippi portion of the original USFWS study (Wicker, 1980) and update it to the 1990s. The mapping of patterns of wetland and other land cover changes in coastal Mississippi not only provides clues to underlying physical (or human) processes, but also provides baseline data essential for further geologic, geographic, hydrologic, biologic, and other investigations.

**Origin and maintenance of coastal wetlands**

Coastal wetlands of the world have developed in regions of low gradients, fine-grained sediments, and low wave energy. Such geomorphic zones include estuaries, lagoons, drowned river valleys, deltas, and exposed coasts sheltered by reefs, barrier islands, or a wide shallow foreshore. Excessive energy in the water—normally wave energy, but also tidal or longshore current energy—will preclude the establishment of wetland vegetation.

Low-elevation coastal wetlands (usually less than 5 ft above sea level in microtidal regimes) may be described by the two sets of processes that account for sediment transport and deposition. Marine-dominated marshes are found in sites subject to sedimentation as a result of tidal or wave action while still protected from erosive wave energy. Examples of such sites include the lee of beach spits, offshore bars, or barrier islands as well as along the margins of protected bays (Mitsch and Gosselink, 1986). The second—and most important in terms of overall areal extent—wetland-creating process is fluvial/deltaic sedimentation. During periods of peak discharge, streams and rivers carrying large sediment loads will deposit the sediments into flood plains within entrenched stream valleys, into protected bays and estuaries, or onto shallow continental shelves. Where levels of erosive wave or tidal action are relatively low, as in estuaries or along exposed coasts with low wave energy regimes, the deposited sediments form a gradual-sloping (i.e., low gradient and relatively wide) land-water ecotone conducive to extensive wetland formation.
Although wetlands prevailed during most phases of geologic history, present-day coastal wetlands are specifically traced to the rise of sea level to its approximate present position about 5000 years ago (Orme, 1990). After the peak of the last continental glaciation about 18,000 years ago, the sea began to rise from a level perhaps 300-400 ft lower than present. Between 15,000 and 7,000 or so years ago, the high rate of sea level rise (0.4 in/yr, or 1.0 cm/yr) precluded any significant growth of wetlands. Most wetland formation dates to around 5,000 years ago when rates of post-glacial sea level rise slowed to less than 0.1 in/yr (0.2 cm/yr) (Nummedal, 1983).

Coastal wetland stability

Under natural conditions, the stability of marsh wetlands is dependent upon the interaction of two categories of processes: relative sea level rise and marsh accretion. High rates of the former, along with low rates of the latter, will restrict regenerative ability and lead to wetland deterioration.

Relative sea level rise is a generalized term that includes both processes of land submergence (subsidence) and processes of water level rise. Since the effect of both processes is a lowering of land surface relative to water levels, it is often difficult to separate the relative magnitudes of each, and thus the term "relative sea level rise" has become adopted. Marsh accretion, specifically vertical marsh accretion, refers to various mechanisms of sedimentation by which the marsh surface builds upward. Sedimentation in marshes may be divided into organic sedimentation, in which decay of organic matter builds up the marsh surface, and inorganic sedimentation, whereby mineral sediments are introduced to the marsh by fluvial or marine processes. Fluvial sedimentation is usually in the forms of overbank sedimentation wherein river-borne sediments are released into marshes as a result of seasonal flooding and overtopping of natural levees and also river-mouth (or deltaic) sedimentation whereby sediments drop out as the hydraulic energy diminishes at the mouth of the river. Marine sedimentation is most often in the form of tidal action redistributing sediments to marshes or storm-triggered wave action dispersing sediments into marshes.

Impacts of future sea level rise on coastal wetlands

Analysis of tide-gauge records and sea-level-rise projections calculated on the basis of global warming rates (Hoffman et al., 1983) infer that, under worst-case scenarios, sea level will rise at a rate equal to or exceeding that of the Holocene transgression (about 0.4 in/yr, or 1.0 cm/yr). Models indicate that, even if marshes keep pace with such high rates (i.e., no marsh accretion deficit develops), the land-water ecotone will become narrower as sea level rises onto the steeper slopes of older coastal uplands. Furthermore, the extensive urban development along the shoreline of the USA will preclude the strip of fringing tidal wetlands from migrating upslope. If sea level reaches a new relative equilibrium, wetlands will not reappear along developed coasts unless processes of sedimentation resume.

Analysis of 100 years of records from the Biloxi, Mississippi, tide gauge reveals that relative sea level has increased 0.6 feet (20 cm)—an average rate of 0.07 in/yr, or 0.18 cm/yr (Burdin, 1991). Although these rates are relatively low, prediction of future rises in these rates has caused concern among coastal Mississippi scientists and policymakers (Burrage, 1991; Otvos, 1991). These concerns are over both acceleration of wetland loss and shoreline erosion as well as potential impacts upon the human occupants and development infrastructure in the Mississippi coastal zone.
MISSISSIPPI'S COASTAL WETLANDS

Distribution of wetlands

Coastal wetlands are found throughout the various micro-environments of coastal Mississippi where conditions ideal for wetland formation exist. These micro-environments include the lower reaches and deltas of streams emptying into Mississippi Sound and adjacent bays, low-energy shore environments of estuarine bays and Mississippi Sound, and lee shores of the offshore barrier islands.

Mainland coastal Mississippi, the focus of the present study, may be described in terms of four drainage systems: the Pearl, St. Louis Bay, Biloxi Bay, and the Pascagoula River (Figure 1). The Pearl and the Pascagoula Rivers—as well as smaller tributaries—downcut their respective valleys during lower sea level stands, and these valleys became drowned as sea level rose during the Holocene. Since that time, extensive sedimentation has filled in most of the valleys which led to a build up of land out into open water (progradation). These sedimentary deposits have provided the foundation for wetland growth.

Besides the fluvio-deltaic wetlands of the lower Pearl River, the Pearl River drainage basin also includes extensive marshes in southern Hancock County. These coastal marshes have formed either directly from sediments contributed via formerly active delta lobes of the Mississippi River or indirectly as a result of wave-sheltering by Mississippi River sediments deposited in the St. Bernard delta (Frazier, 1967).

Mississippi's two semi-enclosed estuarine bays are St. Louis Bay and Biloxi Bay (and Back Bay of Biloxi). The Jourdan River, Bayou La Croix, Wolf River, and several smaller bayous contribute sediments to St. Louis Bay, and fluvio-deltaic and bay-fringing marsh wetlands abound. "Uplands" in the form of coastal pine flatwoods are barely higher than many of the marshes in this area. The Biloxi River, Tchoutacabouffa River, Bernard Bayou, and a few smaller bayous empty into the Back Bay of Biloxi, and several bayous empty into Davis Bayou, an "arm" of Biloxi Bay south of Ocean Springs. As evidenced by all Mississippi's coastal streams, there is a zonation inland from salt marsh to fresh marsh and cypress swamp upstream (Eleuterius, 1973). This gradation is a combined function of gradient (higher elevations upstream) and degree of tidal influence. Fluvio-deltaic tidal marshes are widespread at the head of Back Bay of Biloxi, and small fringing marshes and marsh islands are found throughout the bay system.

The expansive marshes of the lower Pascagoula River (dimensions of about 4 by 7 miles) are the result of extensive sedimentation during the late Holocene and the modern period. Dredging for industrial development in the Pascagoula area has modified much of the natural delta, but some wetlands have evolved on some of the dredged-spoil disposal islands. Wetlands also extend up most of the lower tributaries of the Pascagoula River. Marshes are common east of the city of Pascagoula.
Figure 1. Drainage basins of coastal Mississippi (Oivanki et al., 1995).
to beyond the Alabama state line, and their genesis is traced to fluvio-deltaic sedimentation via a former channel of the Escatawpa River (a present tributary of the Pascagoula), coupled with wave sheltering by the Grand Batture Islands and the offshore Barrier Islands (Meyer-Arendt and Kramer, 1991).

**Previous studies of areal changes in wetlands**

Numerous studies of varying degrees of detail have been conducted in Mississippi's coastal wetlands and adjacent environments. Only a few have attempted to summarize changes in the area of wetlands, however. The following are brief synopses of previous studies.

**Eleuterius' marsh inventory of 1973**

Over two decades ago, botanist L. N. Eleuterius produced what has endured as the comprehensive overview paper on coastal marshes in Mississippi (Eleuterius, 1973). This study was conducted in anticipation of passage of a state Wetlands Protection Act, which was a key component of the Mississippi Coastal Program, which, in turn, was developed in response to passage of the federal Coastal Zone Management Act of 1972 (Graber, 1986). Many scientists, including Eleuterius, were alarmed at the amount of industrialization and urbanization taking place in and adjacent to the coastal wetlands.

In 1973, the Wetlands Protection Law was passed, and practically all of the grandiose plans for wetlands reclamation ground to a halt. Although wetlands removal still takes place (such as to accommodate casinos), the regulatory process has become quite elaborate, and even minor wetlands disturbances are subject to extensive mitigation. The lead agency in the permitting process in Mississippi is the Mississippi Department of Marine Resources, formerly known as the Bureau of Marine Resources.

**The USFWS habitat study of 1980**

As part of the National Wetlands Inventory, a U.S. Fish and Wildlife Service project to map the coastal wetlands of Louisiana and Mississippi was initiated in 1978 (Wicker, 1980). Black-and-white aerial photographs of the mid-1950s and the latest color-infrared high-altitude photography (mostly 1978) were manually interpreted according to a hierarchical classification scheme devised by Cowardin et al. (1979) to evaluate land cover/land use in terms of "habitat" potential for flora and fauna.

The extent of coastal wetland losses along the central Gulf Coast first became apparent as the two sets of habitat maps were quantitatively analyzed (Gagliano et al., 1981). The data showed a reduction in land area of 413,000 acres (11.3% of an original 3,646,000 acres) in southeast Louisiana alone. In comparison to Louisiana's loss of about 650 square miles of land between 1955 and 1978, the overall land loss calculated for coastal Mississippi—over nine square miles (6,055 acres) in approximately the same period—seemed trivial.

Closer inspection of the habitat data revealed that, exclusive of the offshore barrier islands, Mississippi's mainland tidal marsh acreage of 69,130 acres in the 1950s (dates of photography ranged
from the early 1950s to the late 1950s) had dwindled to 64,089 acres by 1978. This loss of 5,041 acres (nearly eight square miles) amounted to a 7.3% loss, a rate approximately 65% that of the deltaic plain of Louisiana (Gagliano et al., 1981). A 1973 estimate of 64,805 acres of mainland marshes (based on 1968 planimetering of the then most recent topographical quads) seemed to indicate that most of the loss took place prior to implementation of the state Wetland Protection Law of 1973 (Eleuterius, 1973).

Meyer-Arendt’s estuarine bay study of 1988

Perhaps because of the perceived effectiveness of the Wetlands Protection Law of 1973, concerns with wetland loss in Mississippi remained low throughout the 1980s. A 1987 report on wetlands in Mississippi suggested that the acreage of tidal wetlands was actually increasing (Eleuterius, 1987).

In 1988, a small study of wetland changes in the two estuarine bays—St. Louis Bay and Biloxi Bay—was conducted by Meyer-Arendt (1989). The data derived from this study yielded results that both confirmed existing knowledge and also identified problems with previous studies. Of the USFWS habitat maps, the 1950s interpretations varied most in accuracy, in part because of poor quality black-and-white aerial photography, and previous marsh acreages for the 1950s may have been overestimated by 2 to 2.5%. Within the estuarine study area, wetland losses of about 2,400 acres between the 1950s and 1985 were attributed to urbanization (60%), dredged spoil deposition in wetlands (15%), and direct conversion to open water (25%) (Meyer-Arendt, 1989).

WETLAND CHANGES IN COASTAL MISSISSIPPI, 1950s TO 1992

The Study Area

Although the official Mississippi Coastal Zone includes all of Hancock, Harrison, and Jackson Counties (Graber, 1986), it was decided to use the initial USFWS criterion, the 15-ft contour as the upper elevation, in the generation of the 1990s land cover data set. This facilitated comparative analysis between the three data sets. Plus, all of the wetland changes and most of other land-water changes would have taken place below this elevation.

This study examined wetland changes in 19 topographic quadrangles (Figure 2). The upper tier of quadrangles (including four close to the Pearl River) were omitted because: 1) little wetland acreage is found there, for the most part, 2) the existent wetlands there, distant from strong tidal and wave influence, appeared to be relatively stable through all years, and 3) the 1991-1992 coverage did not include much of this region. Likewise, the Barrier Islands were omitted for various reasons, including: 1) wetland acreage is relatively small, 2) most land loss on the islands resulted from beach erosion, 3) island land cover changes are monitored by the U.S. National Park Service which administers the Gulf Islands National Seashore (to which all islands except Cat Island belong), and 4) the 1991-1992 coverage did not include much of this region. There were several additional gaps in the aerial photo coverage.
Figure 2. The 15-ft contour in coastal Mississippi limits of the study area (Code numbers correspond to topographic quadrangles as used in Wicker, 1980).
Classification and Mapping

The land cover classification system used in this study consists of a total of seven categories—water, marsh, forest, agriculture, developed, dredged spoil, and beach—plus a "not applicable" (n/a) category for land cover outside of the study area yet within the respective topographic quadrangles. The categories represent a hierarchically "collapsing" of 200+ habitat categories of the widely used Cowardin et al., (1979) wetland classification system:

- **Water** includes all categories of bodies of water, regardless of size, flow regime, floating vegetation cover, degree of human modification, or salinity levels. Mud flats, submerged reefs, and artificial structures built out into water (such as fishing piers) are also included.

- **Marsh** encompasses all grassy wetlands, regardless of salinity or degree of modification by humans.

- **Forest** includes all forms of tree cover regardless of height, ranging from oak-pine uplands to bottomland hardwoods to bald cypress swamps. Scrub/shrub vegetation is also included. If tree cover on pasture lands consisted of dispersed single trees (not clumps) and constituted less than about 15% cover, no forest category was delineated.

- **Spoil** consists of dredged material that has been disposed of above water. It may be barren or lightly colonized by upland or wetland vegetation. However, if a type of land cover, such as forest or development, is now found at a site where originally dredged spoil was deposited, then that category is used in place of the spoil category.

- **Agriculture** includes both cropland (row crops or tree crops) as well as pasture land. It also includes portions of Mississippi's coastal savannas which consist of "open pine forest" (with less than 15% tree cover) where the open grassland is used for seasonal grazing of cattle.

- The **developed** category includes all forms of structural development, from light residential to heavy industrial. If a subdivision has been platted in a coastal pine forest, and streets and utilities have been laid out, then the "developed" category should be used (even if the subdivision is not yet filled in with homes).

- **Beach** includes the various types of sand beach. In Mississippi, the sand beach classification is applied mostly to the wide, artificial beaches found in all three coastal counties. Natural beaches, many of them less than 10 feet wide, were often difficult to map at the 1:24,000 scale.
METHODS AND RESULTS

Mapping and Data Manipulation

The mapping of the 1992 overlays entailed preparing stable base maps from the respective U.S. Geological Survey topographical quadrangles. Longitude/latitude, the 15-ft contour, and various control points such as highway intersections and stable waterways (tidal channels and bayous) were mapped onto the overlays. Color infrared aerial photography—1991-1992 imagery in 9×9, ‘distortion-free,’ 1:24,000 format acquired from the U.S. Army Corps of Engineers. Mobile District—was used to interpret the various land cover categories. By using the control points derived from the topographic maps, the 1992 map interpretations were formatted to the stable base overlays. The final overlays were prepared upon stable Mylar® acetate film for digitizing and entering into the computer database. The earlier data sets were acquired on computer tape from the U.S. Fish and Wildlife Service.

To standardize the data, several adjustments had to be made. The 15-foot contour interpretation was found to be inconsistent for the three time periods studied because of inconsistencies in interpretation methods. To facilitate comparable land-use comparisons between the data sets, the 1992, 15-foot contour interpretation was superimposed on the prior data sets. However, where there was an obvious man-made elevation change, such as land-filling on Singing River Island (Pascagoula South quadrangle), the 1992, 15-foot contour was not superimposed on the earlier data sets.

Land cover changes in coastal Mississippi, 1950s to 1992

Analysis of the resultant data reveals that many significant changes in wetland cover and land use have taken place since the 1950s in coastal Mississippi. There has been a decrease in total land area within the study area of 2,670 acres, down from 194,746 acres (Figure 3). This has been exceeded by the over 8,500 acres of marsh lost during the same period, a reduction of 13% of the 67,000 acres measured in the 1950s. Only about one quarter of this acreage (2,300 acres) is attributed to direct conversion of marsh to water, an area roughly equivalent to the total amount of land lost. Most of the marsh-to-water conversion is accounted for by shore erosion and marsh deterioration, but canalization is also a factor. Nearly 40% of the marsh loss is directly related to replacement by developed land, which seems to imply that "human processes" play a greater role than natural processes in wetland loss. The developed land use category tripled from 14,000 acres in the 1950s (7% of the total area) to nearly 43,000 acres in 1992 (22% of the total area). This rate of development is, of course, a great underestimate of the overall amount of industrial and residential development that has taken place in Mississippi's coastal counties because only land below the 15-ft contour was examined within this study.

The most significant aspects of the data are the documentation of land loss—especially wetland loss—in coastal Mississippi. The data show that while overall rates of land loss have decreased slightly in the later interval (late 1970s/early 1980s to 1992), rates of wetland loss appear to have increased since 1978. Closer analysis of the individual topographic quadrangles reveals that such apparent increases reflect inaccuracies in photo interpretation and mapping, especially of several quadrangles (notably the Waveland quadrangle) which were remapped in 1982 by the USFWS.
Figure 3. Summary of overall changes in total land area, developed land, and marsh in coastal Mississippi, 1950s-1992 (Ovianki et al., 1995).

Although there were inaccuracies and inconsistencies noted, especially in the 1950s, 1970s, and 1982 data, overall generalizations regarding changes in land cover can be made. In addition to recognition of patterns for the entire coastal study area, more detailed observations can be made on a county and even a topographical quadrangle basis.

Overall patterns by county

Closer inspection of the land loss and marsh loss data reveals the variability among Mississippi's three coastal counties (Figure 4). Values of marsh loss are much higher than those of total land loss in all three counties, which reflects the high incidence of conversion of marsh to other uses throughout coastal Mississippi.

Conversion of marsh to water and marsh to development were the leading reasons for marsh loss in coastal Mississippi, but there was much variability among the counties. Replacement of marsh with developed land use and with water accounts for almost 96% of all marsh loss in Hancock County, whereas in Jackson County development and conversion to water account for less than 47% of marsh loss. In Jackson County, there has been a natural aggradation of sediments within the Pascagoula River alluvial valley and subsequent conversion of marsh to forest as wetland species of trees (such as bald cypress) colonized increasingly fresher and better-drained soil.

A trend of overall increase in developed land characterized all three counties. The lower rate of increase in Harrison County (slightly less than doubling) as compared to the other two counties may
be explained by higher rates of urbanization and industrialization in Harrison County in earlier times. Previously vacant or agricultural sections of Hancock and Jackson Counties are increasingly subject to processes of suburbanization as the local economies remain strong (most recently fueled by legalized casino gaming).

Overall patterns by topographic quadrangle

More specific trends of land cover and land use changes in coastal Mississippi can be identified by more detailed analysis of each of the 19 topographic quadrangles included in the study. The following sections summarize changes recorded over the entire study period. More detailed data, especially regarding the various changes in land cover categories between the various years, are available from the Mississippi Office of Geology in Jackson.

Changes in total land area

In terms of changes in total land area between the 1950s and 1992, several geographic patterns can be easily recognized (Figure 5). Although most of the topographic quadrangles exhibit stability in terms of overall land change, both the far eastern and the far western quads display great fluctuations. Severe land loss (over 400 acres) is restricted to two quadrangles—Grand Island Pass and Grand Bay SW—both of which are similar in terms of land cover. The data and land cover maps reveal that natural processes of shore erosion and marsh deterioration—whereby marsh breaks up and is replaced by open water—are the main reasons for the high rates of land loss.
Mississippi Coastal Zone

GAIN

- >500 acres
- no significant change

LOSS

- ★★ 50-200 acres
- ★★★ 200-400 acres
- ★★★★ >400 acres

Figure 5. Change in total land area by topographic quadrangle, 1950s-1992 (Oivanki et al., 1995).
Moderate land loss has taken place in the Waveland, Gautier South, and Pascagoula North quadrangles. In Waveland, suburbanization has led to the creation of numerous impoundments (reservoirs) and also much dredge-and-fill activity (Plate 1). Shore erosion and marsh deterioration are also important in Gautier South and Pascagoula North. Insignificant or low rates of overall land loss characterize 12 of the 19 quads. The minimal land loss that did occur is attributed to a combination of shore erosion, marsh deterioration, and canalization.

The only quadrangle showing land gain is Pascagoula South, where a net gain of nearly 600 acres was measured. This gain is partly attributed to natural sedimentation and also colonization of subaerial dredged spoil deposits, but a greater part is attributed to spoil deposition and development thereon. This development includes industrial development in Pascagoula and lower Bayou Casotte and the establishment of the U.S. Navy homeport on Singing River Island, an island created by repeated deposition of dredged spoil.

Changes in total marsh area

Changes in total marsh area between the 1950s and 1992 similarly exhibit great variability among the topographic quadrangle sheets (Figure 6). The greatest loss of marsh is recorded on the Waveland, Kreole, and Grand Bay SW quadrangles. In Waveland, most of the loss is explained by residential development in marsh environments. To a lesser degree, the natural processes of shore erosion, marsh deterioration, and overestimation of marsh area in the 1950s account for the marsh loss. In Grand Bay SW, the marsh loss has resulted from a combination of shore erosion and marsh deterioration and accounts for practically all of the land loss noted for this quadrangle. On the other hand, the marsh loss documented for the Kreole quadrangle is not real. Low sparse pine savanna and pasture lands were erroneously interpreted as marsh for the 1950s and 1970s, in part because of the difficulty in separating these land cover categories on black-and-white imagery. On the higher-quality 1992 color-infrared imagery, it was much easier to distinguish the categories more accurately. Another important factor is logging. Many of the coastal pine forests were clear-cut in the 1930s and 1940s, and much of the pine savanna was probably still quite sparse in terms of tree cover at the time of the 1950s imagery. Regrowth by the time of the 1970s and 1992 imagery may account for the greater forest cover identified in those time frames.

The second tier of quadrangles experiencing high rates of marsh loss includes Biloxi, Gautier North, and Pascagoula North. In Biloxi and Gautier, marsh loss is explained by marsh deterioration and conversion to open water, conversion to development, and overestimation of the 1950s marsh acreage. In Pascagoula North, aggradation of alluvial sediments has led to swamp forest replacing fresh marshes in the northern part of the quadrangle. Also, much dredge-and-fill caused loss of marsh in the vicinity of the Gulfport power plant and along the lower Escatawpa River where commercial, industrial, and residential development has been extensive.

Moderate rates of marsh loss, ranging from 300 to 600 acres over the total time span, are found in the English Lookout, Grand Island Pass, Bay St. Louis, and Gautier South quadrangles. The first two quadrangles contain vast acreages of the Hancock County coastal marshes, and both shoreline erosion and marsh deterioration account for the moderate rate of marsh-to-water conversion noted there. The marsh loss in Bay St. Louis reflects marsh-to-development conversion, quite similar to
Plate 1. Recreational urbanization near the confluence of Bayou la Croix and the Jourdan River, Hancock County (Waveland quadrangle). Photo by K. J. Meyer-Arndt.
Figure 6. Change in total marsh area by topographic quadrangles, 1950s-1992 (Oivanki et al., 1995).
the adjacent Waveland quad. Development in marsh wetlands was also noted in Gautier South, but, for the most part, the apparent marsh loss has resulted from gross overestimation of marsh area in the 1950s (and also in the 1970s) data set. The remainder of the quadrangles displayed little change in marsh acreage.

Changes in total developed area

The final land cover category examined for regional variability in patterns and quadrangle-level trends was development (Figure 7). The highest rates of development were related to industrial development in the Pascagoula and Gulfport urban areas and also suburbanization throughout the region from Bay St. Louis to Pascagoula (Plate 2). Lowest rates of development were found in both the older established urban centers as well as in quadrangles covered by extensive marsh and water. The focus on changes in total developed area was stimulated by an initial assumption that loss of land, and especially loss of marsh land, was directly correlated with the degree of urbanization and commercial/industrial development.

Waveland and the Pascagoula North and Pascagoula South quadrangles exhibited the highest degree of development—over 2500 acres total—within the designated study area over the 1950s-to-1992 period. Development in the Waveland area was mostly related to recreational urbanization (i.e., summer home subdivisions), but development in the Pascagoula area was mostly industrial (i.e., shipbuilding, U.S. military, and pulp mill). In all cases, marsh wetlands were affected by the high rates of development over the period. The high rates of development are still going on in the mid-1990s, and industrial expansion continues in Pascagoula and casino gaming has stimulated residential expansion in Harrison and Hancock Counties, including the Waveland quadrangle.

High rates of development, between 1,400 and 2,500 acres over the period of study, were recorded for the Bay St. Louis, Gulfport North, Biloxi, and the Gautier North and South quadrangles. Moderate rates of development were noted in Ocean Springs and Pass Christian as well as in three quadrangles that contain extensive marsh wetlands. Low or even extremely low rates of development were restricted to topographic quadrangles in which much of the land portion of the quadrangles had already been quite developed in the 1950s (notably Gulfport South), to quads that contained small acreages of upper tributary valleys in which development pressures had not yet set in (such as Kiln and Vidalia), or to coastal quadrangles in which either little land existed for development and/or the land was ill-suited for widespread development. This latter category includes the Grand Island Pass and the Deer Island quads.

SUMMARY AND IMPLICATIONS FOR THE FUTURE

The mainland coast of Mississippi was subject to air photo analysis for three time periods from the 1950s to 1992 to determine relative changes in land use and land cover. The focus was upon the relationship between wetland changes, development, and overall land loss. The study revealed that over 8,500 acres of marsh disappeared since the mid-1950s, a loss of 13% of the state's coastal wetlands. At the same time, the acreage of developed land below the 15-ft contour tripled from 14,000 acres in the 1950s to nearly 43,000 acres in 1992. In urban areas, development has been
Figure 7. Change in total developed area by topographic quadrangle, 1950s-1992 (Oivanki et al., 1995).
Plate 2. Suburban encroachment on wetlands, Fort Bayou, Jackson County (Ocean Springs quadrangle).  
*Photo by K. J. Meyer-Arndt.*
responsible for most of the marsh loss, whereas in rural areas marsh loss has been associated with
natural processes of erosion and marsh degradation (including a marsh accretion deficit).

The comparative analysis also revealed serious misinterpretations of land cover in previous photo
interpretation studies, and wetlands in particular were overestimated in the 1950s and 1970s data
sets. Such interpretation errors made it difficult to analyze trends for the individual intervals (e.g.,
1950s to 1970s, 1970s to 1992), although the overall patterns (for the entire period) were apparent.
In spite of the shortcomings, this study represents a first effort at understanding basic changes in land
cover and land use categories of the lower elevations of the Mississippi Coastal Zone, especially
changes in marsh wetlands.

As Mississippi's wetlands continue to be subject to pressures of waterfront development and rising
sea level, loss of these valuable resources will continue also. Since the legalization of dockside
casino gaming in Harrison and Hancock Counties in 1992, over a dozen casino complexes have
opened (Meyer-Arendt and Abusalah, 1994; Meyer-Arendt et al., 1994). Not only have wetland
losses accompanied construction of some of the existing casinos, but many remaining available sites
are in estuarine bay settings where the potential for marsh destruction is greater. Although gaming
permits are granted only following a lengthy permitting process, and potential wetlands impacts must
be "mitigated" (i.e., offset by protection or creation of wetlands elsewhere in the general area), the
potential for significant adverse environmental impacts remains high.

This study was important both in terms of documenting trends and also in terms of establishing
starting points for future analyses. The Mississippi coastal zone is a very dynamic environment as
a result of both physical and human-induced processes, and it is important that the patterns resulting
from these dynamic processes are understood by scientists and land-use planners. The role of
wetlands is now recognized as being important not just for natural coastal ecosystems but for the
coastal economy as well. Mississippi must monitor changes in wetlands, whether natural or
human-induced, to preserve this valuable natural resource for the future.

BIBLIOGRAPHY

Engineer Waterways Experiment Station, Technical Report WRP-DE-4, 101 p.

Long-term implications of sea level change for the Mississippi and Alabama coastlines:
Mississippi-Alabama Sea Grant Consortium, Proceedings, Papers, Outlines, Abstracts presented in

Burrage, D. D., ed., 1991, Long-term implications of sea level change for the Mississippi and
Alabama coastlines: Mississippi-Alabama Sea Grant Consortium. Proceedings, Papers, Outlines,

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe, 1979, Classification of wetlands and
deepwater habitats of the United States: Washington, D.C., U.S. Fish and Wildlife Service,
FWS/OBS-79/31, 103 p.


* This article is adapted from a report (Land Use/Land Cover Changes in Mainland Coastal Mississippi, 1950s to 1992, submitted to the Office of Geology, Mississippi Department of Environmental Quality by Klaus J. Meyer-Arendt and Barbara Yassin in June 1994) and a publication (Oivanki, S. M., K. J. Meyer-Arendt, & B. Yassin, 1995, Analysis of Land Use and Land
Klaus J. Meyer-Arendt was a former geographer at Mississippi State University with research interests in coastal environments. He presently is Professor and Chair, Department of Environmental Studies, University of West Florida. His research ranges from physical geography-coastal processes and shoreline erosion, changes in wetlands, to cultural geography (historical human impacts upon coastal areas, patterns of tourism development). His regions of expertise include the U.S. Gulf Coast, Mexico and Central America, and the Caribbean. In addition, Klaus Meyer-Arendt is the coordinator of the Mississippi Geographic Alliance, an organization supported by the National Geographic Society and the State of Mississippi and dedicated to improving geographic education in K-12 education.

Born into a shipping family in Hamburg, Germany, he emigrated—with his parents—to Brazil and on to the United States (Ohio, Utah, and Colorado) before settling in the foothills of the Coast Range in Oregon. After stints of living in California and Alaska’s Aleutian Islands and traveling throughout Latin America, Klaus completed his BA degree in Geography and a Certificate in Latin American Studies at Portland State University in 1975. For graduate studies, Klaus went to Louisiana State University to pursue his interests in the cultural-historical geography of Latin America, and he received a MA degree in Geography in 1979.

While a master’s student at Louisiana State University, Klaus developed a strong interest in coastal studies. He worked on various projects in the Mississippi River Delta and along the state’s Barrier Islands. From 1978 until 1983 he worked at Coastal Environments, Inc., in Baton Rouge, Louisiana, as a coastal morphologist and coastal management advisor. In addition to working on a major land loss study funded by the U.S. Fish and Wildlife Service. Klaus worked on various research and management projects throughout the Louisiana Coastal Zone. In 1983 he returned to LSU to
complete a Ph.D. dissertation on patterns and environmental impacts of coastal resort development around the Gulf of Mexico. A Ph.D. in Geography was conferred in 1987.

Dr. Meyer-Arendt came to Mississippi State University in 1987 after short teaching stints at LSU and Southeastern Louisiana University. His research quickly shifted to the Mississippi Gulf Coast, where he conducted several research projects for the Mississippi-Alabama Sea Grant Consortium and the Office of Geology of the Mississippi Department of Environmental Quality. Since casino gaming was introduced to the Mississippi Gulf Coast during the period of active research, Klaus began to track the patterns and impacts of this new industry. Several publications resulted from those research projects, and synopses have been presented at meetings of the Mississippi Planning Association, and the National Council for Geographic Education. His co-edited book *Casino Gambling in America: Origins, Trends, and Impacts* was published in of 1997 by Cognizant Communication Corporation.

Klaus J. Meyer-Arendt also maintains active interests in tourism research, especially in Latin America. In addition to publishing on resort development in Mexico and the Dominican Republic, Klaus has conducted several MSU field trips south of the border. In 1994 he received a prestigious Fulbright Senior Scholar Research Award to study domestic tourism development and shoreline erosion along the north coast of Yucatan, Mexico.

Dr. Klaus J. Meyer-Arendt, assumed the post of Professor and Chair, Department of Environmental Studies, University of West Florida, 1100 University Parkway, Pensacola, FL 32514. Telephone 850-474-2746 (dept.), 850-474-2792 (direct), Fax: 850-857-6036. E-mail:kma@uwf.edu