ANALYSIS OF SHORELINE EROSION AT SARGENT BEACH, TEXAS AND PROJECTION OF SHORELINE POSITIONS IN THE YEARS 2000 AND 2050

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Introduction

The greatest losses of coastal land in Texas occur along highly erosional deltaic headlands having relatively narrow and steep beaches. This type of beach occurs south of Sargent, Texas, a small community located on the western flank of the Holocene Brazos-Colorado delta (figs. 1 and 2). At Sargent Beach, the transgressive beach deposits are composed of sand and gravel (shell and rock fragments) derived from relict sediments exposed on the inner shelf. Whole and broken surf-zone, shelf, and bay species constitute the biogenic detritus; bay species (*Crassostrea virginica*, *Rangia cuneata*, and *Mercenaria* spp.) are the most abundant shell material concentrated on the beach and in the adjacent washover terrace. This mixed bay-estuarine shell assemblage is eroded from the Holocene delta-plain muds as the shoreline retreats.

Sargent Beach is far removed from major sediment sources (river mouths) and human activities that directly influence shoreline changes. For that reason it is significant that the area has experienced the highest long-term and short-term rates of erosion along the Texas coast (Seelig and Sorensen, 1973; Morton and Pieper, 1975; Sealy and Ahr, 1975). Accelerated erosion at Sargent Beach since 1930 (fig. 3) is probably related to significant reductions in sediment supplied by the Brazos River (Morton and Pieper, 1975; Mathewson and Minter, 1976) rather than to the relative rise in sea level. The shoreline of the Holocene Brazos-Colorado delta has been retreating for the past few thousand years, but construction of dams and relocation of the Brazos River channel have recently caused substantial reductions in the amount of sand delivered to downdrift beaches (Morton, 1979).

When sandy beaches are severely eroded during a storm, at least some of the sand eventually returns to the beach and promotes partial if not complete recovery. But when muddy beaches are severely eroded, they do not recover because the coarse-grained sediment (sand and shell) is deposited on the upland surface as an overwash terrace. At the same time, the fine-grained sediment transported off the beach is deposited in deeper water on the continental shelf. Thus, the beach retreats in an abrupt stepwise progression without the benefit of any significant transport of sand after the storm.

In 1980 Hurricane Allen created an unusual beach morphology. Locally the resistant marsh muds formed a low wave-cut bench. The bench exhibited a rhythmic pattern due to the nearly uniform spacing of erosional reentrants and miniature pocket beaches. Seaward of the bench were low, circular pillars of mud that stood as remnants of a former "breaker

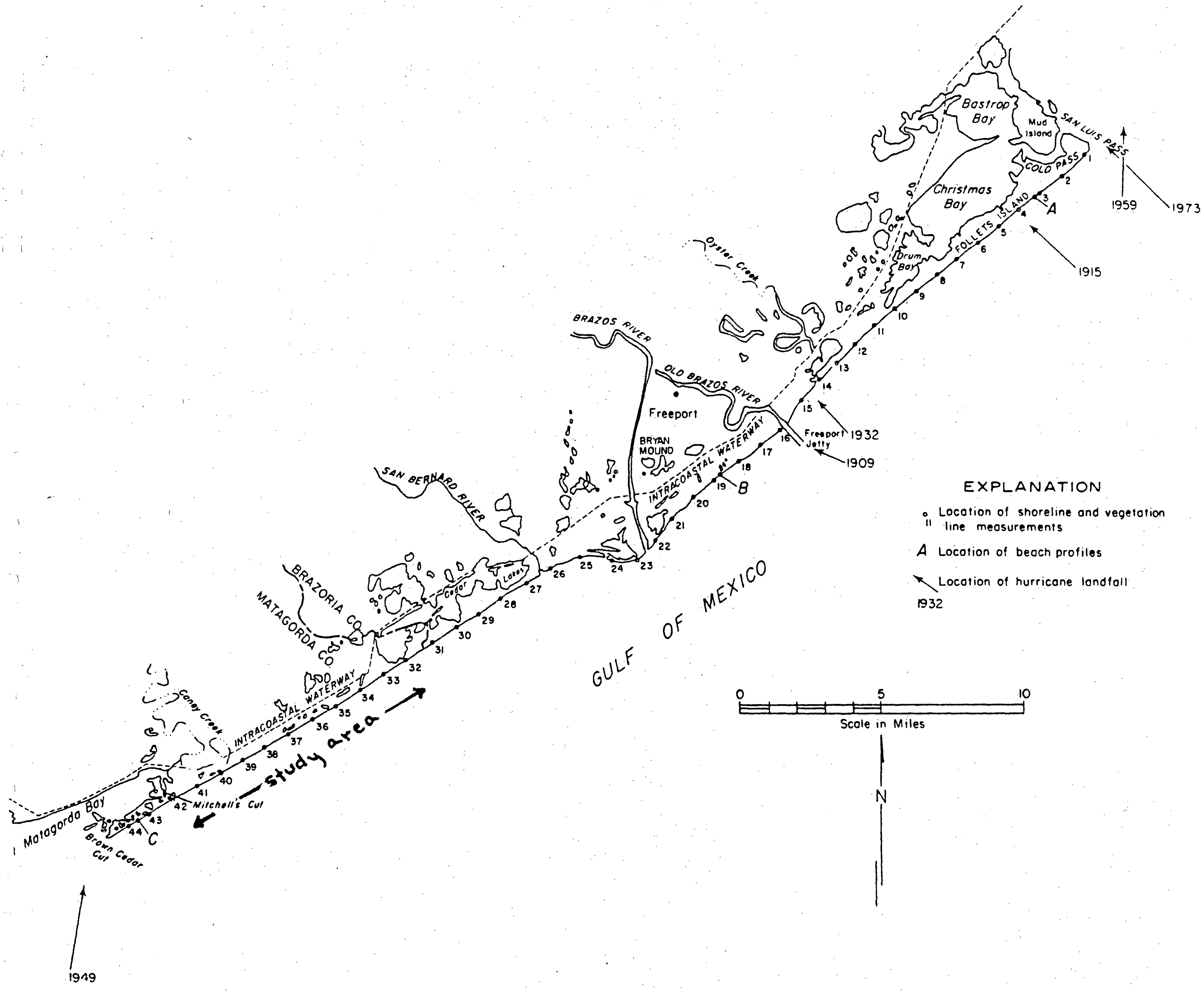


Figure 1. Ten-mile segment of the Texas Gulf shoreline referred to as Sargent Beach. Station numbers are referenced in the text and in figures. Modified from Morton and Pieper (1975).

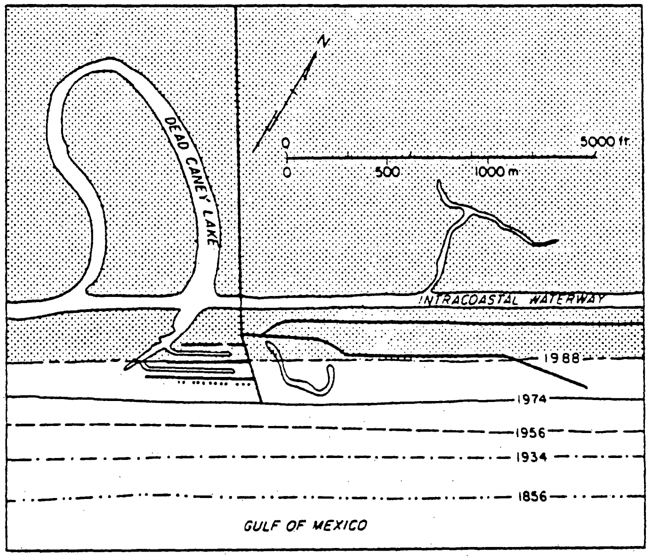


Figure 2. Historical shoreline changes at Sargent Beach between 1856 and 1988. From Pilkey and others (1989).

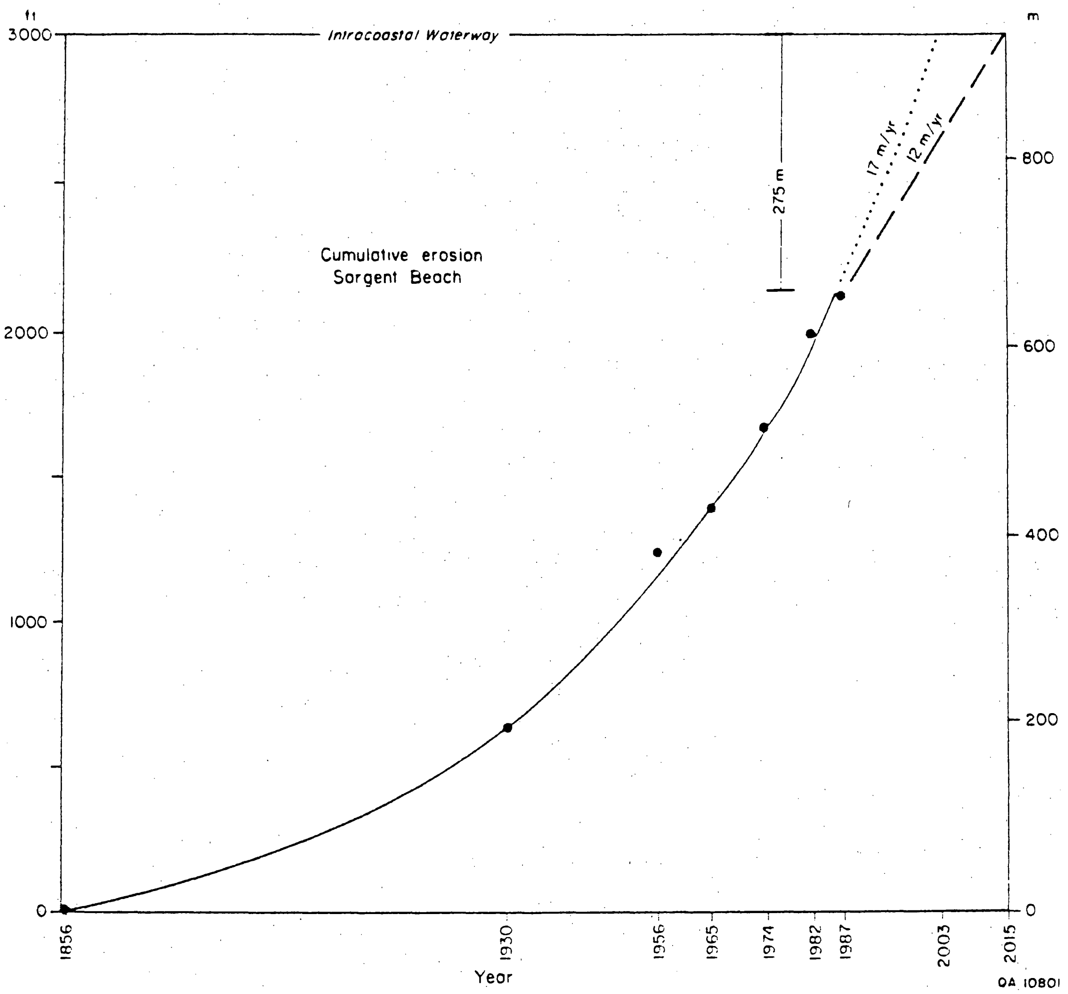


Figure 3. Recent acceleration in rates of shoreline erosion at Sargent Beach. From Pilkey and others (1989).

bar" scoured in the mud beach. Eventually, wave action removed the abrupt break in slope, and the beach assumed a more uniform profile.

Projections of current rates of shoreline retreat at Sargent Beach indicate that the Gulf Intracoastal Waterway will be threatened shortly after the turn of the century. Residents and government authorities are concerned that barge and boat traffic along the Waterway could be disrupted, thus causing severe economic losses to the transportation industry. Because of the potential economic impacts related to beach erosion, an analysis was made of the past and current rates of erosion at Sargent Beach and projections of shoreline position in the year 2000 and 2050 without any attempt to mitigate the erosion (*without project*). Projections of shoreline position for the same years were also made in conjunction with a proposed seawall (*with project*) that would serve to protect the Waterway from future erosion.

Analysis of Erosion Rates

Both aerial photographs and beach profiles were used to evaluate historical rates of Gulf shoreline erosion at Sargent Beach. These independent analyses, which yielded similar results, permitted the investigation of time dependent variations in erosion rates as well as comparisons of long-term trends (> 100 yrs) and most recent trends (decades).

Aerial Photographs

Erosion rates at Sargent Beach derived from aerial photographs and topographic maps between 1853 and 1982 were summarized by Morton and Pieper (1975) and Paine and Morton (1989). The most recent low-altitude aerial photographs available for the study were taken in March, 1987 by the Texas General Land Office. The Gulf shoreline (wet beach-dry beach boundary) mapped on these photographs was transferred to U.S.G.S. 1:24,000 topographic maps using a Saltzman optical projector. A microrule was used to measure distances between the 1982 and 1987 shorelines at reference stations 32-42, which are shown in fig. 1. Rates of erosion at each station were calculated by dividing the distance between the 1982 and 1987 shorelines by the elapsed time. These monitoring techniques, the potential sources of error, and rates of erosion at the same reference stations are described in more detail by Morton and Pieper (1975) and Paine and Morton (1989).

Alongshore variability in erosion rates for five time periods ending in 1930, 1957,

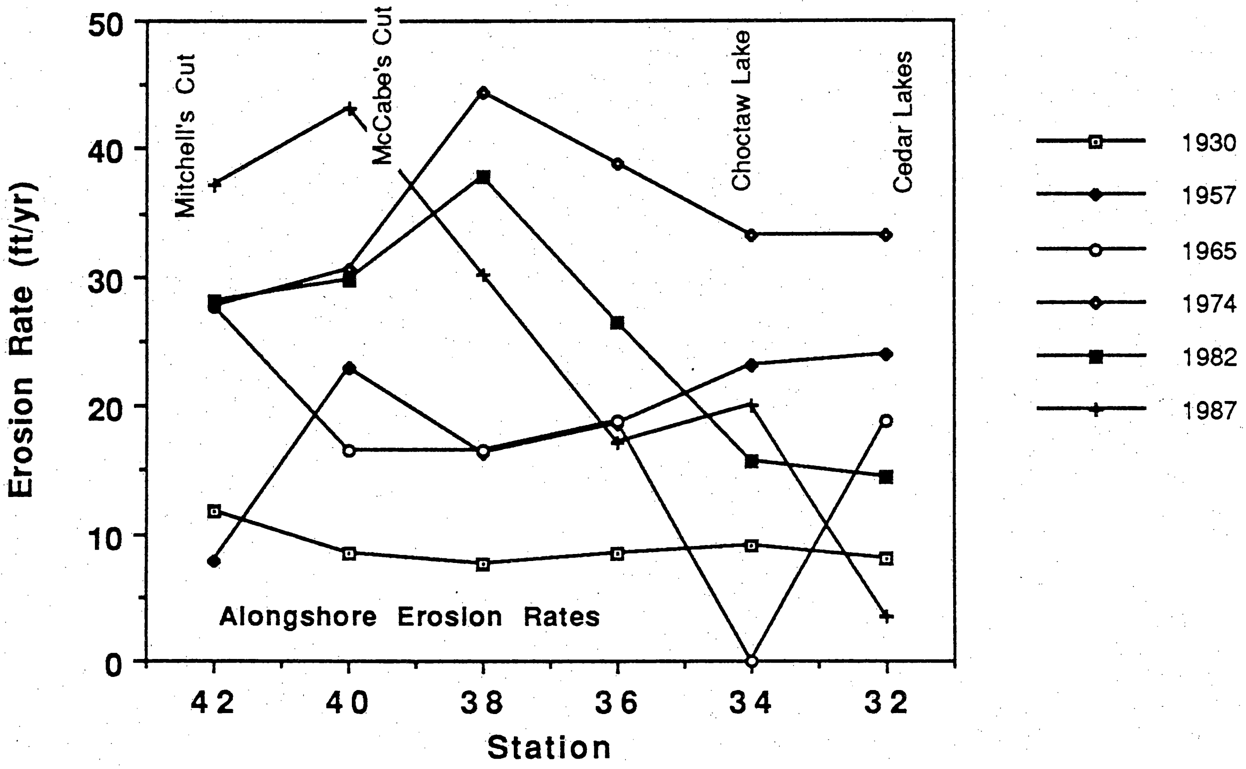


Figure 4. Alongshore rates of erosion at stations 32-42 between 1930 and 1987. Data from Morton and Pieper (1975), Paine and Morton (1989), and this study.

1965, 1974, 1982, and 1987 are shown in fig. 4. This composite plot demonstrates that erosion rates (1) are not temporally constant, (2) are not spatially uniform, and (3) the position of maximum erosion varies for each time period. Shifts in the position of maximum erosion are related to shoreline rhythms, variations in longshore sediment transport, and the natural variability in coastal processes (Morton, 1979). This means that an averaging technique is needed to accurately predict future shoreline positions. The plot also shows that erosion rates generally increased between 1930 and 1974 but either decreased or remained nearly the same between 1974 and 1982. The rates of erosion abruptly decreased in the Cedar Lakes area between 1982 and 1987; however, high rates of retreat persisted near McCabes Cut during the same time period. The decrease in erosion rates at the updrift end of the beach segment near the San Bernard River and the new Brazos River strongly suggest that sand transported southwestward by Hurricane Alicia in 1983 is temporarily reducing the deficit in sediment budget that previously existed (Morton, 1988).

A map of nearshore surface sediments (White and others, 1988) provides additional evidence of the sediment source and direction of sediment transport responsible for the reduced erosion (Plate 1). The map shows slightly coarser sediments downdrift (southwest) of the San Bernard River and the new Brazos delta.

Plots of cumulative erosion between 1853 and 1987 at stations 32-42 (figs. 5-7) illustrate the long-term average rates of beach erosion between Cedar Lakes and Brown Cedar Cut as well as the general acceleration in erosion rates. A second order polynomial curve provides the best statistical fit for each plot. By extending the x-axis (time) these plots can also be used to predict future shoreline positions, e.g. the year 2000 (figs. 5-7).

Beach Profiles

Profile S-4 (Plate 2), located near FM 457, was surveyed in January 1989 by the Galveston District, Corps of Engineers. This profile was projected into the midpoint survey line of Station 20+00 (U. S. Army Corps of Engineers, 1980) using the ground distance between the survey baselines to control horizontal position and mean sea level (zero line) to control elevation. Horizontal and vertical scales are the same for both profiles. The resulting composite profile was used to estimate recent erosion rates and to estimate the depth of forebeach erosion.

The beach at the mean sea level intercept is composed of stiff clay and therefore is not subject to seasonal fluctuations in position as is the case for sandy beaches. Consequently, this boundary was judged to be the most reliable for determining rates of erosion from the

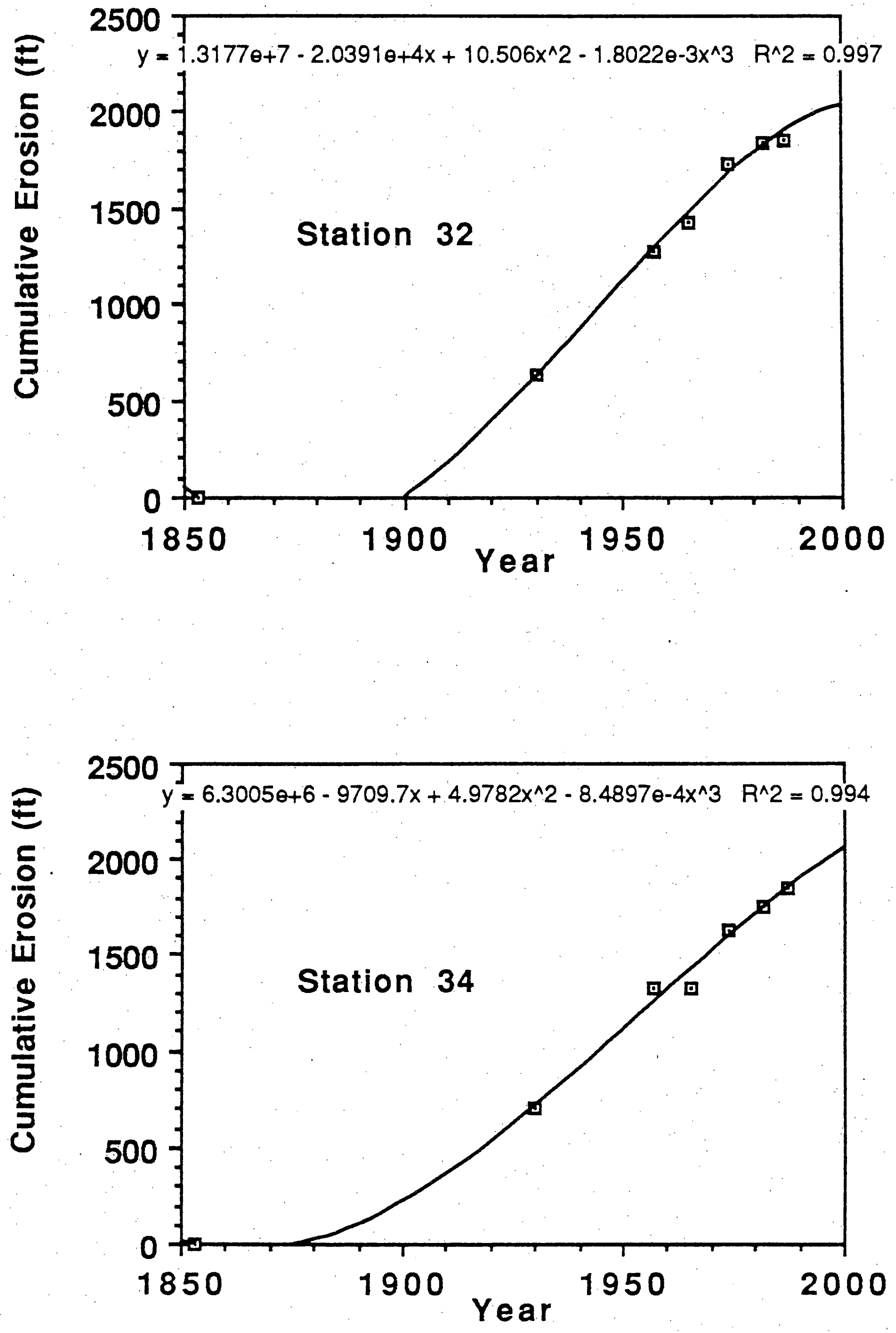


Figure 5. Cumulative erosion at stations 32 and 34 between 1853 and 1987.Data from Morton and Pieper (1975), Paine and Morton (1989), and this study.

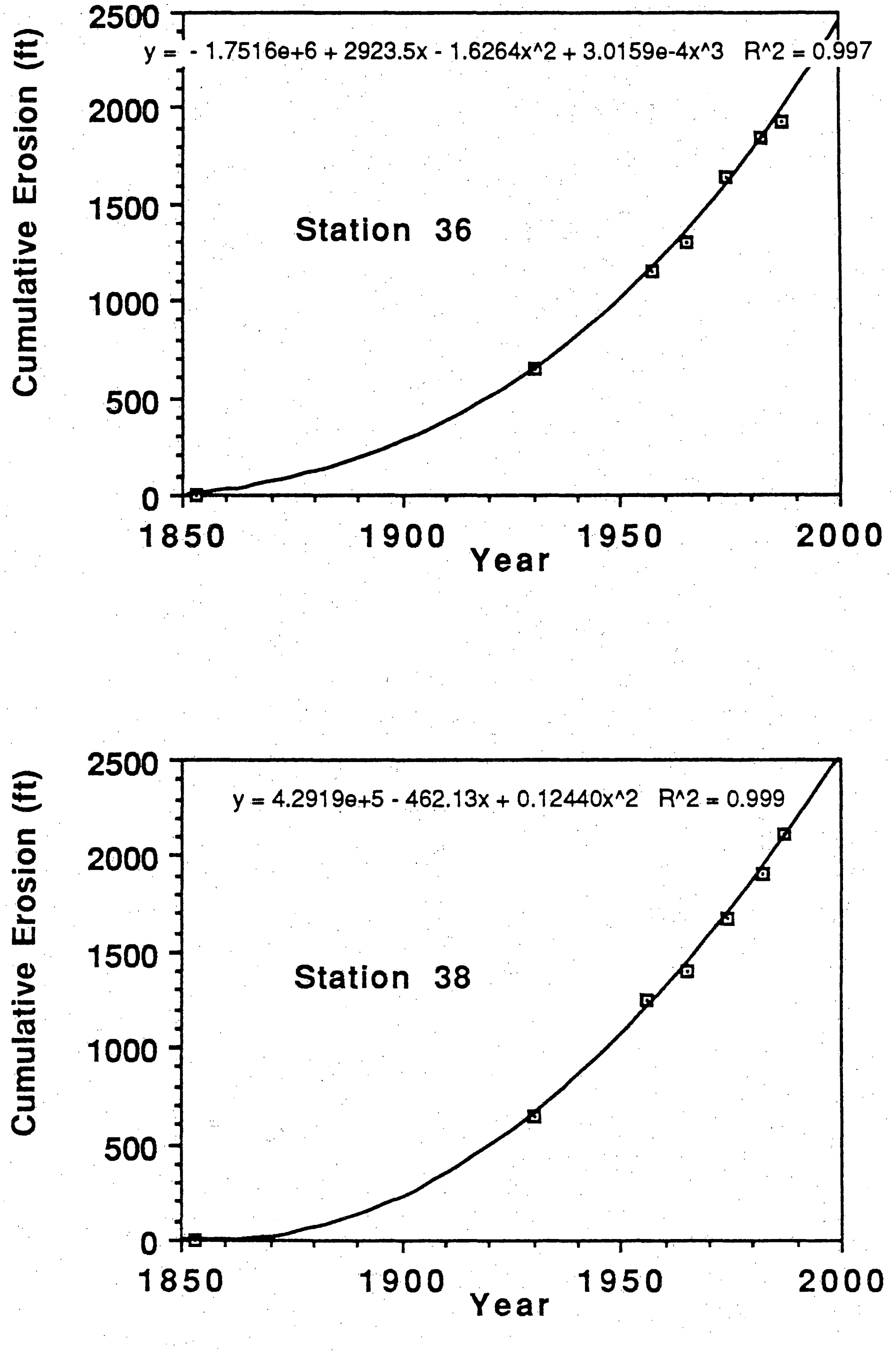
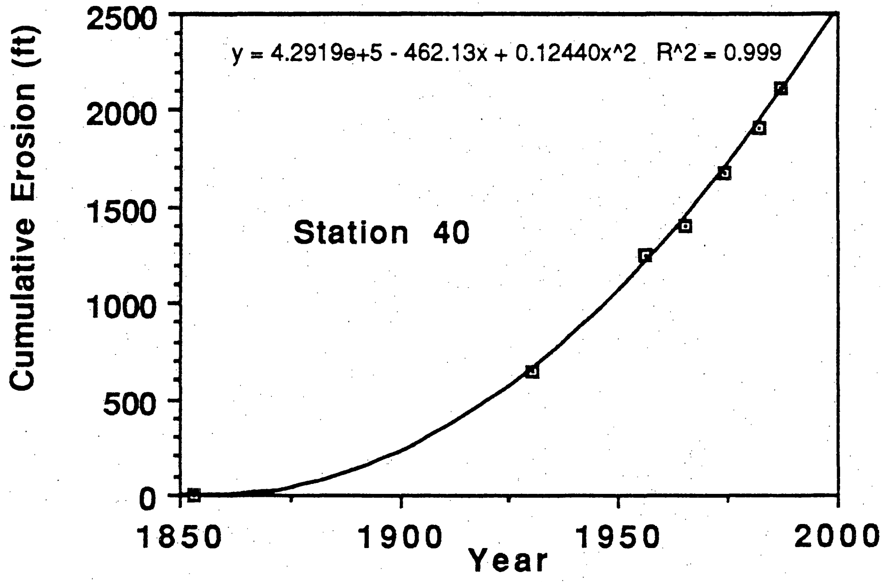


Figure 6. Cumulative erosion at stations 36 and 38 between 1853 and 1987. Data from Morton and Pieper (1975), Paine and Morton (1989), and this study.



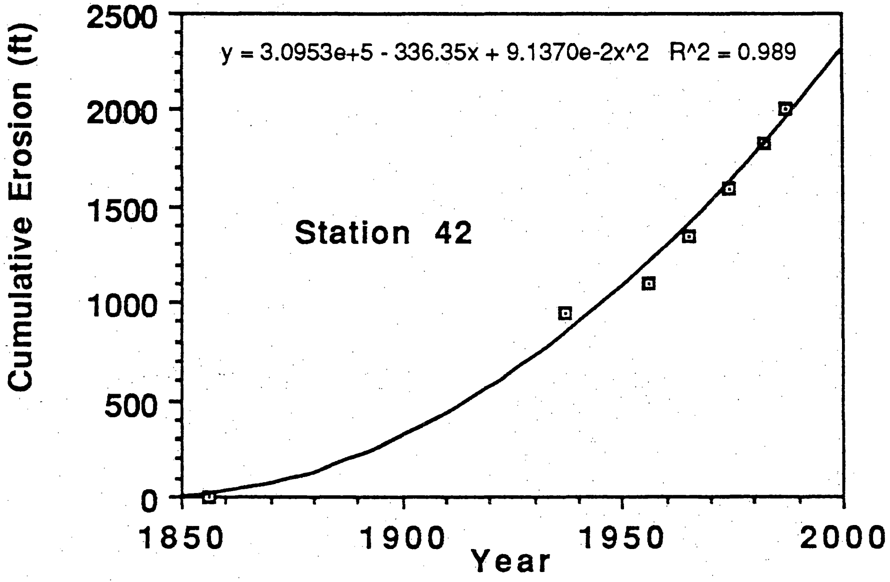


Figure 7. Cumulative erosion at stations 40 and 42 between 1853 and 1987. Data from Morton and Pieper (1975), Paine and Morton (1989), and this study.

beach profiles. Between the end of October 1978 and January 1989, the mean sea level intercept moved landward 330 ft, or at an average rate of about 33 ft/yr. This rate of erosion is similar to recent rates for the same area calculated from the graphs of cumulative erosion (figs. 3 and 6). A higher rate of retreat (about 44 ft/yr) is obtained by comparing the change in berm position between 1978 and 1989. This erosion rate is considered to be less reliable than the rate determined from the mean sea level intercept because the berm is composed of mobile sediments. These unconsolidated sediments, which are deposited as a washover terrace, form a thin veneer of sand and shell over the stiff clay. The berm and forebeach slope is lower in 1989 than in 1978, thus causing the apparent higher rate of erosion (Plate 2).

Analysis of Volumetric Losses

The volume of sediment eroded from the Gulf shoreline between stations 32 and 42 (fig. 8) was estimated for five time periods (1853-1930, 1930-1956, 1956-1965, 1965-1974, and 1974-1987). This was accomplished by planimetering areas between the sequential shorelines, multiplying the areas by a constant depth of erosion (see below), and dividing by the associated time period to normalize the data and to estimate the annual deficit in sediment budget. The 1970-1978 beach profiles (Plate 2) show that the depth of erosion is a minimum of about 6 ft below sea level. This depth plus the average surface elevation of 5 to 6 ft gives a total minimum eroded thickness of about 12 ft.

Annual volumetric losses for the ten-mile segment accelerated from 183,170 cu yd/yr in 1930 to 590,867 cu yd/yr in 1974 and then decelerated to 528,833 cu yd/yr between 1974 and 1987. The recent deceleration in volumetric loss reflects the reduced erosion rates in the Cedar Lakes area.

Projected Shoreline Positions

Year 2000 and 2050 Shorelines Without Project

The projected position of the Gulf shoreline was determined using two independent methods. The first method relied on the average rates of erosion between 1965 and 1987 at stations 32-42. These stations were divided into two groups because erosion in the Cedar Lakes area is slower than that at the other segment. Average erosion rates for the past 22 years at stations 32-36 have been about 25 ft/yr whereas those to the southwest (stations 38-42) have been about 33 ft/yr. Projected locations of future shorelines were determined

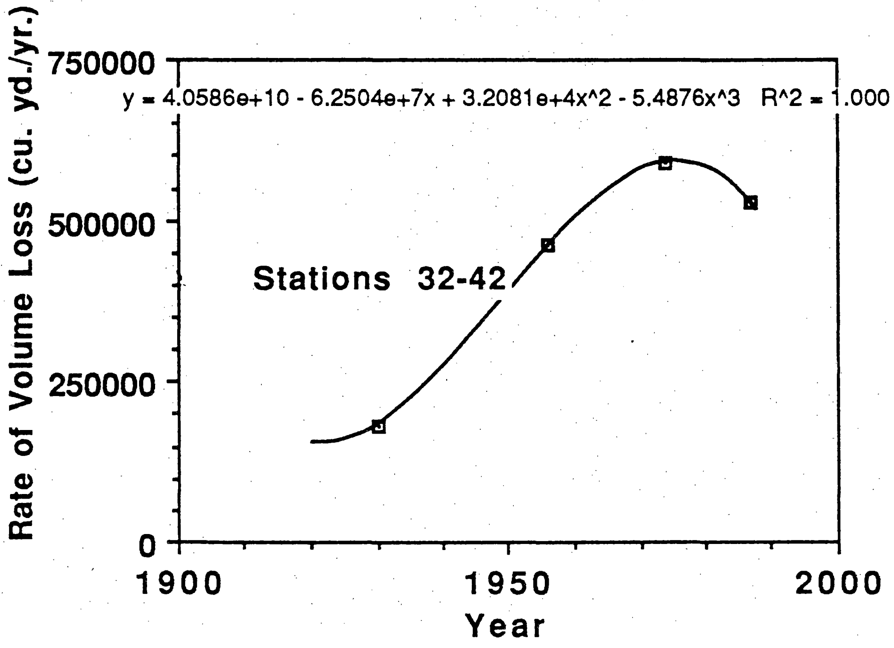


Figure 8. Volumetric rate of land loss along the ten-mile segment of Sargent Beach between 1930 and 1987.

by (1) calculating distances using these rates and the appropriate time interval and (2) plotting the shoreline position using the 1987 shoreline as the baseline. The differential rates of erosion used at points 36 (25 ft/yr) and 38 (33 ft/yr) cause a slight offset in the year 2050 shoreline that was smoothed to provide a more reasonable shoreline alignment.

Location of the year 2000 shoreline was also predicted by using the cumulative erosion plots (figs. 5-7). The y-axis intercept of the regression curve provides an estimate of total erosion between 1853 and 2000. Plotting this distance inland from the 1853 shoreline gives a projected position that is similar to the one derived on the basis of average erosion rates.

Year 2000 and 2050 Shorelines With Project

A proposed seawall alignment was drawn 300 ft seaward of the Gulf Intracoastal Waterway as depicted on U.S.G.S. topographic maps. Because the year 2000 shoreline lies seaward of the proposed seawall, the projected shoreline position is unaffected by the seawall. The year 2050 shoreline would be at the seawall except where it bends inland into Cedar Lakes and East Matagorda Bay. At the Cedar Lakes location, the year 2050 shoreline is essentially the same as the *without project* shoreline.

The 2050 shoreline at the East Matagorda Bay location was determined as follows. If the shoreline continues to erode at an average rate of 33 ft/yr, then the seawall and shoreline will coincide about the year 2010. Assuming a slight acceleration in erosion rate of about one-third (12 ft/yr) attributed to the seawall itself, then 40 years of erosion at 45 ft/yr would put the year 2050 *with project* shoreline about 500 ft landward of the year 2050 *without project* shoreline.

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