

# COASTAL ENGINEERING

## Chapter 24

### HISTORY OF THE GALVESTON SEA WALL

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Galveston Island, one of the long narrow barrier beaches that fringe the Gulf Coast of Texas, is a low, sandy formation about 28 miles long and from  $\frac{1}{2}$  to 3 miles wide. In its natural state the Gulf shore was bordered by an area of sand dunes rising to heights of 12 to 15 feet above the natural surface of the island. The availability of deep water along the bay side of the island led to the early development of the city of Galveston on the east end of the island. In its early days the city was protected from hurricane tides by the sand dunes along the Gulf front. The rapid development of the city in the latter part of the 19th century, especially its increasing importance as a summer resort, led to the removal of the sand dunes along the beach front for fill and to permit easy access to the beach. Without the dunes the city was unprotected from the fury of the hurricanes. The danger to the city was realized by a number of persons, and several plans for storm protection had been developed; however, because of financing difficulties and general public apathy none of these plans was carried out. Figure one shows a map of Galveston Island with development as it was in 1900.

The resort city of about 38,000 persons was exposed to the havoc of the hurricane of September 8, 1900. The hurricane winds of this storm and accompanying 15-foot tide that swept the city caused property damages reported to be over \$25,000,000, and a loss of more than 6,000 lives. The damage along the Gulf front was complete: In about 1,500 acres along the Gulf front over 2,600 houses were destroyed and up to 300 feet of land were lost by erosion of the shore.

The citizens of Galveston responded to the destruction of the city with remarkable energy and fortitude and within four years had erected a barrier to the sea that was to save the city from further devastation within 15 years and which still makes Galveston a comparatively safe place in which to live.

About one year after the storm the City Commission of Galveston and the County Commissioners Court of Galveston County appointed a board of engineers to report on means for protecting the city. The board was composed of Brigadier General H. M. Robert, United States Army, retired; and Messrs. Alfred Noble and H. C. Ripley. The board was directed to report on the following:

1st. The safest and most efficient way for protecting the city against overflows from the sea.

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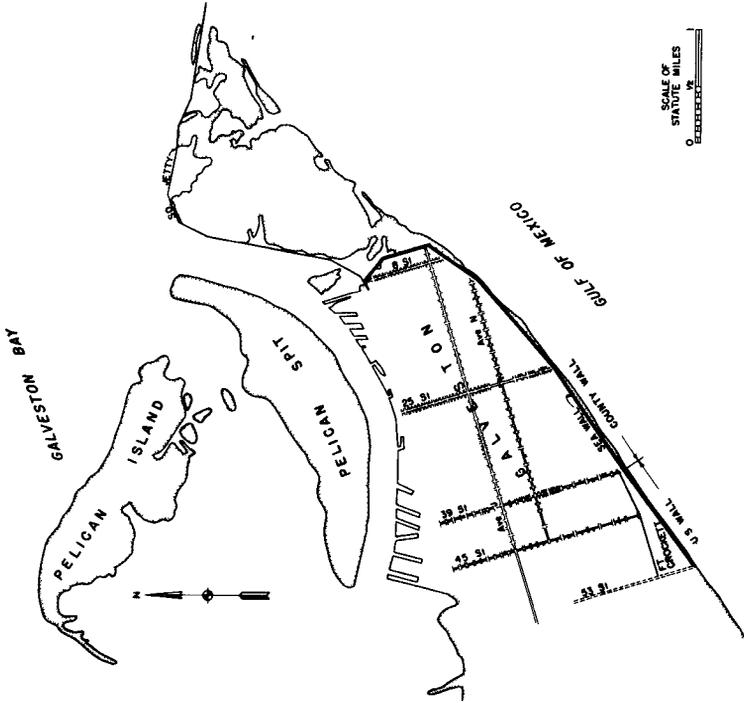


Fig. 2.  
Galveston Island showing initial sea wall construction by Galveston County and the United States.

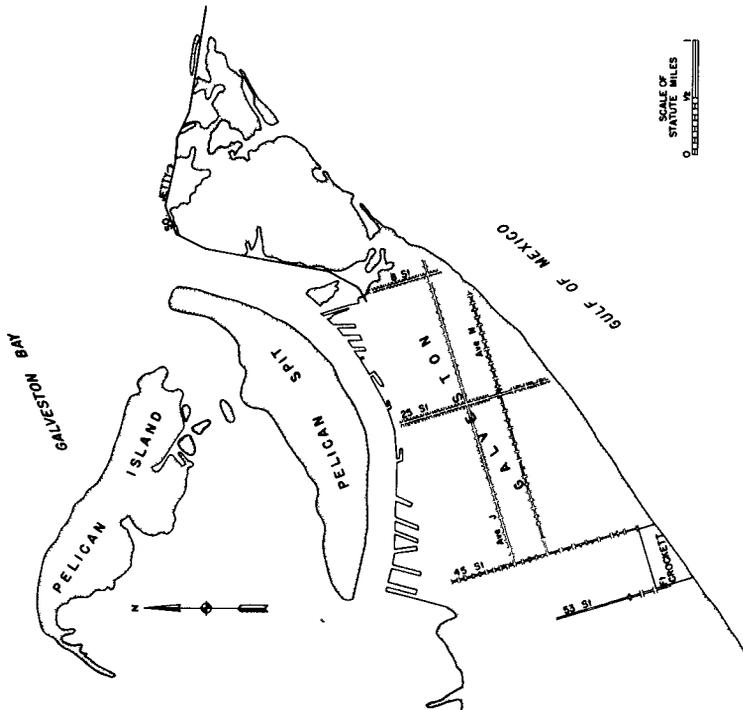


Fig. 1.  
Galveston Island about 1900.

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2nd. Elevating, filling, and grading the avenues, streets, sidewalks, alleys, and lots of the city so as to protect the city from overflow from the waters of the Gulf, and to secure sufficient elevation for drainage and sewerage.

3rd. A breakwater or sea wall of sufficient strength and height to prevent the overflow of and damage to the city from the Gulf.

The Roberts Board submitted its report on January 25, 1902, recommending in general the following plan for protection of the city:

a. A solid concrete wall, over 3 miles long, connecting with the south jetty near 8th Street; thence to 6th Street and Avenue D; and thence on 6th Street across the island to the beach and down the beach as far as 39th Street. The top of this wall to be 17 feet above mean low water. The location of this sea wall would be landward of the highwater line generally at about the 3-foot contour as shown on figure 2.

b. The raising of the city grade to 8 feet at Avenue A, 10 feet at Broadway, 12 feet at Avenue P, and continuing this slope to the sea wall, which corresponds to a rise of one foot in 1,500 feet from the bay toward the Gulf.

c. The making of an embankment on top of this fill adjacent to the wall, and rising to a height of 18 feet above low water at a distance of 200 feet from the wall, thence sloping down on a grade of 1 in 50 to the surface of the fill. The top of this embankment for 35 feet from the sea wall to be protected by a brick pavement and 60 feet farther by Bermuda grass. A section of the structure proposed by the Roberts Board is shown on figure 3a.

The design of the sea wall provided for a concrete gravity section 16 feet wide on the base at elevation 1 foot above mean low water and 5 feet wide on top at elevation 17 feet above mean low water. The sea face of the concrete sea wall to be curved so that its upper portion will be vertical, to give the wave an upward direction and prevent, to a great extent, its running up and over the embankment behind the wall. The wall would be founded on piles and protected from undermining by sheet piling and a layer of riprap 27 feet wide and 3 feet thick extending outward from the toe of the sea face of the wall. The riprap to be deposited so that when the work is finished the larger stone will be on the surface with interstices closely filled with smaller pieces, the object being to present a surface as smooth and resistant to wave action as practicable without incurring great expense in placing the stone.

The cost of the sea wall was estimated at a total of \$1,295,000 for the 17,593 feet of sea wall. This portion of the sea wall was constructed by Galveston County, beginning in October 1902 and completed in July 1904 at an actual cost of \$1,581,673.30. The structure was built generally in accordance with the plans of General Robert, except that the embankment

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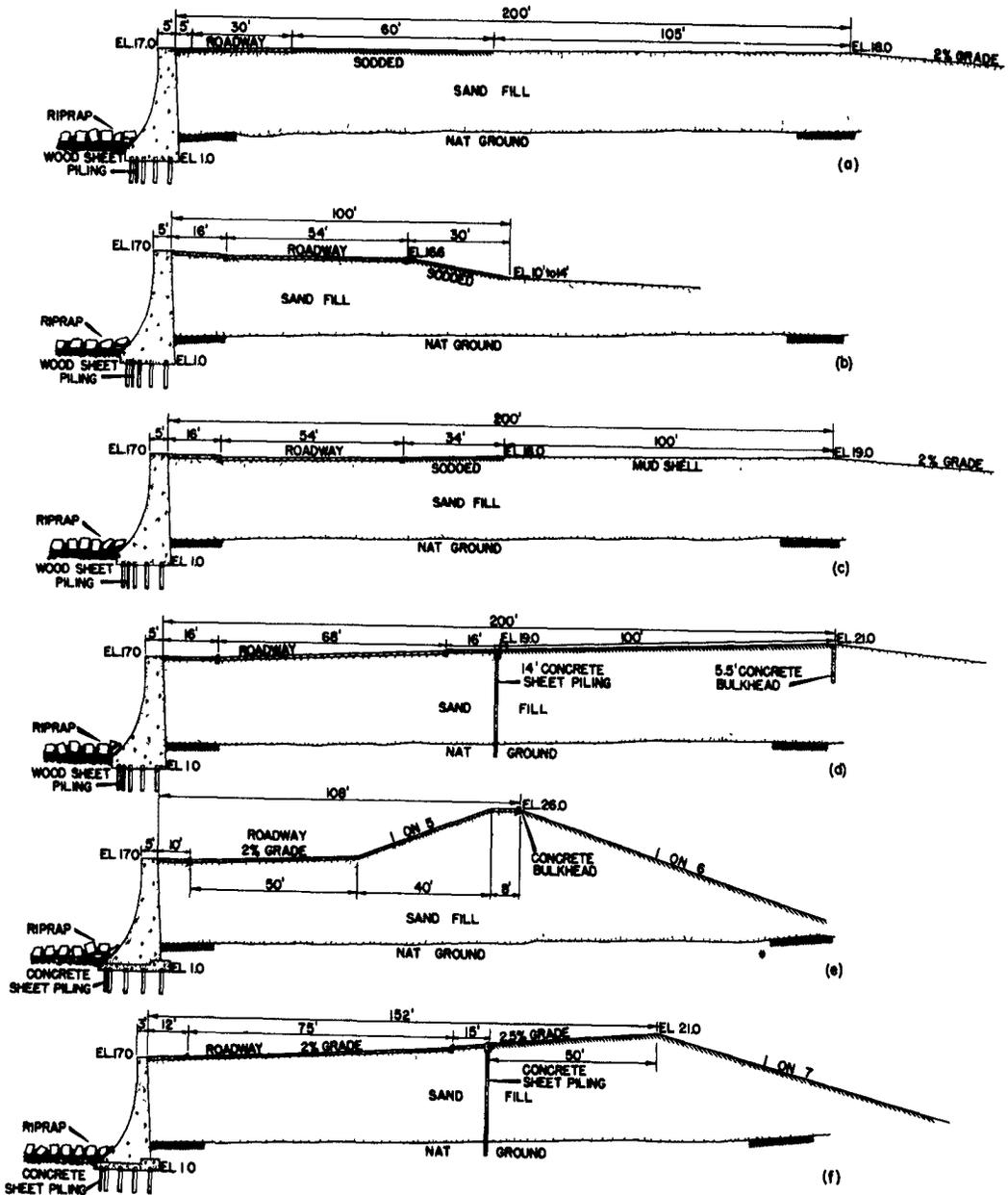


Fig. 3. Cross sections of the sea wall.  
 a. As proposed by the Roberts Board.  
 b. As initially built by Galveston County.  
 c. As modified after the 1909 storm.  
 d. As modified after the 1915 storm.  
 e. As built in front of Fort San Jacinto.  
 f. Authorized 3-mile west extension.

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behind the concrete section was built only 100 feet wide and to a maximum elevation of 16.6 feet. The wall as built is shown on figure 3b.

While the county sea wall was being constructed the U. S. Congress authorized the construction of a sea wall of similar design along the front of the Fort Crockett Military Reservation. This reservation is located between 39th Street and 53rd Street, beyond the end of the county sea wall. The Fort Crockett sea wall is 4,935 feet long and ties in three concrete gun emplacements on the reservation. It was constructed immediately following completion of the county wall at 39th Street, being started in December 1904 and completed in October 1905. The cost to the United States was \$295,000, exclusive of the fill behind the wall.

The concrete section of the Fort Crockett wall is similar to the county wall as recommended by the Roberts Board. Behind the wall the entire reservation was filled to a grade of 17 to 18 feet, and 34 feet of the fill adjacent to the concrete wall was protected with paving.

The sea wall was soon subjected to a minor test, when in 1909 an intense hurricane of small diameter crossed the Texas coast about 45 miles southwest of Galveston. The accompanying storm tide reached about 6.6 feet above mean low water. Considerable quantities of water were thrown over the sea wall and drained across the fill into the city. The slope of the sand embankment behind the wall was considerably scoured by the flow of water and some of the roadway paving was undermined. The riprap along the toe of the wall was lowered somewhat and in a few places the wooden sheet pile cut-off wall was exposed.

The toe of the wall was repaired by placing sand and riprap to bring the riprap up to grade. As a result of the damage to the embankment caused by this storm it was decided to repair the embankment behind the wall and extend the fill to a crest elevation of 19 feet at a distance of 200 feet from the face of the concrete section as originally proposed. The section as repaired and modified after the 1909 storm is shown on figure 3c.

In 1913 a report was prepared at the request of Congress by a special board of engineers for rivers and harbors, which considered the question of extending the sea wall eastward from 6th Street to Fort San Jacinto in the east end flats. This report pointed out the danger of storm erosion cutting a channel across the island in this area, which would breach the jetty and result in extensive shoaling in the Galveston channel along the bay side of the island. The board considered this danger sufficient to warrant preventive measures and recommended that the sea wall be extended across the east end flats to protect the harbor from blockade by storms and to permit expansion of the harbor facilities. The recommended extension from 6th Street to the first battery at Fort San Jacinto had a total length of 10,300 feet of which

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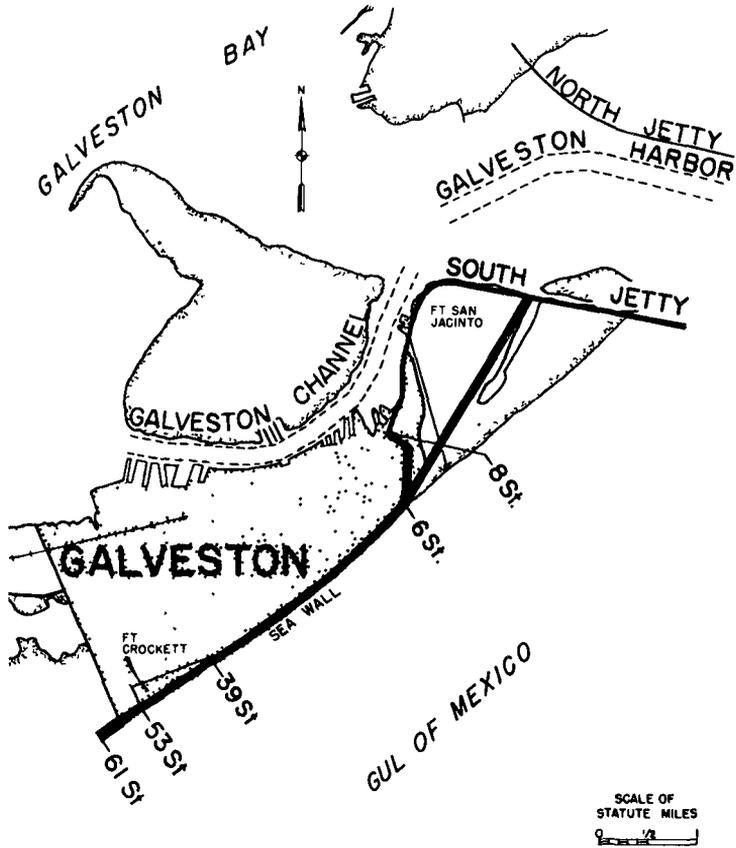


Fig. 4. Galveston Island showing sea wall extension to the south jetty and to 61st Street.

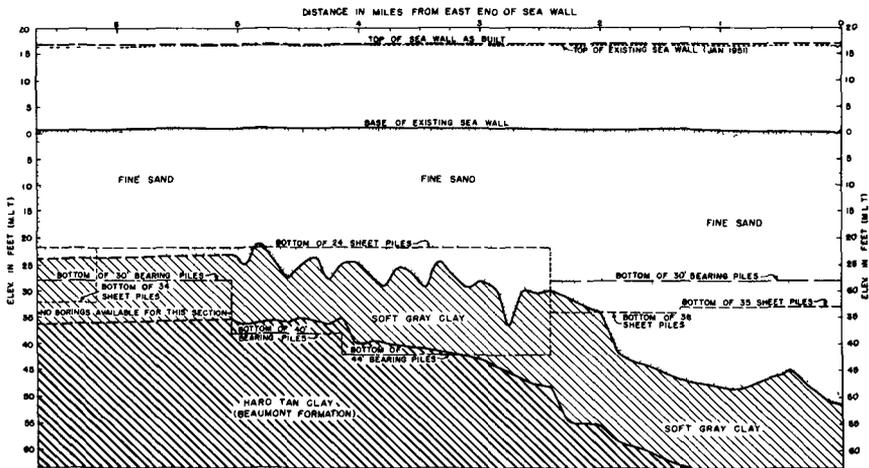


Fig. 5. Soils profile along the existing sea wall.

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3,300 feet would be built by the local interests, city or county, and 7,000 feet on the Fort San Jacinto Reservation would be built by the United States. This proposed extension is shown on figure 4. The design of the sea wall extension was the same as the completed sea wall with the embankment behind the wall 200 feet wide from the edge of the wall to the crest of the fill.

In 1915 the sea wall was subjected to its most severe test, in fact probably as severe a test as it will ever experience, for the tropical cyclone that crossed the Texas Coast on August 16, 1915, about 30 miles southwest of Galveston, was a major hurricane fully as severe as the storm of 1900 that wrecked such havoc in the city.

The sea wall proved the adequacy of its design in protecting the city from a repetition of the damage it had experienced in 1900. In Galveston the loss of life in 1915 was only 12 and the total property damage was estimated at \$4,500,000, both many times less than that caused by the 1900 storm.

The 1915 storm was accompanied by a tide that reached nearly 14 feet above mean low water and wave crests that are estimated to have reached a maximum height of about 21 feet. The storm was of particularly long duration, being several times that of the 1900 storm, and the storm tides inundated the city for over 40 hours.

The heavy waves caused considerable scour along the foot of the sea wall. The riprap apron was undermined in many places, dropping as much as 3 feet below the toe of the wall, and exposing the timber sheet pile cut-off wall. This was of particular concern since the untreated timber was exposed to teredo damage. The exposed reaches were filled with sand and riprap as rapidly as possible. Over 24,000 tons of riprap were placed along the toe of the wall to repair the storm damage.

The most extensive damage to the sea wall was the erosion of the embankment back of the wall by the great quantity of water that was thrown across the wall. One observer reported that water appeared to be coming over the wall in a continuous sheet about two feet deep. The embankment was scoured out and the pavement destroyed completely from 6th Street to 18th Street. Several houses and buildings near the sea wall were undermined by the scour and destroyed. Between 18th Street and 21st Street the embankment was protected from scour by buildings. West of 21st Street the embankment was washed down from 7 to 8 feet and the brick paving was damaged, and from 39th Street to 43rd Street, in front of Fort Crockett, the embankment with road and sidewalk paving was washed back into the city. There was considerable scour from 43rd Street to the end of the wall at 53rd Street.

The concrete section of the sea wall was damaged to the extent of two small chips of about two cubic feet each near 39th Street. This was caused

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by a four-masted schooner which was blown over the wall during the height of the storm while dragging two anchors. The anchors caught on the toe of the wall and the schooner pounded to pieces on top of the wall. Fragments of the hull, masts, and cargo were scattered over the west end of the town.

Before the storm there was a beach generally along the Gulf side of the wall, as much as 300 feet wide in places. After the storm the beach had completely disappeared and there was a depth of 3 to 4 feet at the toe of the riprap. The beach sand was in a bar deposited several hundred feet off-shore from which a large quantity gradually moved inshore but the beach has never built up above low tide to any extent since the storm.

Because of the extensive damage to the sea wall, the county requested General Robert to review the problem and report on a plan to furnish further protection against hurricanes. His recommendations were that the paving on top of the embankment be extended to a width of 100 feet; that a reinforced concrete sheet pile bulkhead be placed along the land side of the pavement, with a top elevation of 19 feet; and that the embankment rise in another 100 feet to an elevation of 21 feet at 200 feet from the wall.

This work was done immediately and in addition a small concrete bulkhead, 1 foot thick and 5 feet high, was constructed at the crest of the embankment. The sand fill beyond the paving was protected by sodding or by a cover of shell.

Figure 3d shows this modification.

On July 27, 1916, Congress authorized the east extension of the sea wall from 6th Street to Fort San Jacinto as recommended by the board of engineers in 1913. This extension is shown on figure 4. Work on this extension was begun on June 20, 1918. The work was very much delayed by wartime labor shortages and lack of materials because of embargoes on railroad cars. The extension was about half completed, having reached the edge of an old borrow pit about 200 feet wide and  $2\frac{1}{2}$  feet deep from which about 3,000,000 cubic yards of material had been removed for the Galveston grade raising, when the severe hurricane of September 13-14, 1919, occurred. The borrow pit had been closed with a wood sheet pile bulkhead and work of constructing the sea wall across the area was in progress when the storm occurred. This storm passed about 180 miles south of Galveston but it caused a tide of 9.0 feet above mean low tide and winds of about 60 miles an hour at Galveston.

The high tide covered the east end flats with several feet of water and caused strong currents around the end of the completed wall that scoured the borrow pit to a width of about 2,000 feet with a maximum depth up to 19 feet and an average depth of about 8 feet. It was necessary to place about 250,000 cubic yards of sand fill in the scoured

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channel. The fill was slow in draining and considerable difficulty was experienced in constructing the wall across this reach.

The volume of water thrown over the sea wall during this storm was not large and there was little damage behind the wall except in the section at the Fort Crockett Reservation that had been washed out in the 1915 storm. Here the embankment had been replaced but had not been paved and sodded. The sand fill was scoured to depths of 2 feet to 12 inches between the wall and the sheet pile bulkhead 100 feet from the wall.

West of 39th Street the riprap at the toe of the wall was deficient in quality and quantity, being small in size and partly of sandstone. This rock was scattered and lowered for a distance of several hundred feet and in places the wood sheet piling were exposed. About 6,000 cubic yards of rock were required to repair this section of the wall.

The east extension of the wall to the battery at Fort San Jacinto was completed in March 1921. In the last 4,660 feet of this wall reinforced concrete sheet-piles were used for the cut-off wall under the toe of the sea wall, and the riprap apron was omitted because of the protection afforded by the wide foreshore in front of the wall.

A somewhat different design was used for the embankment behind the sea wall across the San Jacinto Reservation. Here the embankment behind the wall has a 10-foot walk and 50-foot roadway that slope up on a 2 percent slope and then the embankment rises on a 20 percent slope for 40 feet to a crest of the fill at elevation 26 feet. The crest is 8 feet wide and there is a concrete cut-off wall along its landside that extends one foot above the top of the fill. Behind the cut-off wall the fill has a 1 on 6 slope to the natural ground at a distance of about 250 feet from the face of the concrete wall. The front slope and crest of the embankment are paved. This embankment is designed to prevent any overtopping of the fill by storm waves. A section of this wall is shown on figure 3e.

A further extension of the sea wall eastward across the Fort San Jacinto Reservation to the south jetty was authorized by Congress in 1922, and was constructed between May 1923 and January 1926. This extension of 2,860 feet in length was of the same design as the completed wall on the reservation.

In 1926, Galveston County constructed a west extension of the sea wall from 53rd Street to 61st Street. This section, 2,800 feet in length and of the same design as the county wall in front of the city, was completed in June 1927.

The completion of this section brought the sea wall to its present condition. The total length of sea wall constructed is 38,490 feet, or

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7.29 miles, of which 23,755 feet was constructed by Galveston County and 14,735 feet was constructed by the United States. The effective length of sea wall along the Gulf front is 6.64 miles. The cost of the sea wall totaled \$6,130,000, and the cost per foot varied from \$90.00 a foot for the first construction in 1902 to \$200.00 per foot for the construction in 1926.

A profile of the sea wall from 61st Street to the south jetty is shown on figure 5. This profile shows the subsurface strata which consists of about 25 feet of sand underlain by 10 feet of soft clay below which is the heavy clay of the Beaumont Clay formation. The east end of the profile shows the erosion of the gorge of Galveston pass. The bearing piles under the wall are generally seated in the clay strata, except in the east end where the depth to clay is too great, and the section west of 39th Street where short piles were used.

The profile of the top of the wall, in figure 6, shows the extent of settling that has occurred in the wall. The oldest part of the sea wall has settled least because of the use of longer bearing piles, the tips of which extend into or near the Beaumont Clay formation. Settlement of the wall has been caused, mainly, by consolidation of the soft gray clay beneath the tips of the piles that do not reach the Beaumont Clay. Settlement has been very uniform at any one locality along the sea wall and no cracking or shifting of the monoliths is evident. Settlement has been continuous since the sea wall was constructed and apparently is continuing. The greatest settlement occurred in the east end of the sea wall which was constructed over recent deposits. Here the soft gray clay layer is much thicker and it appears that this area was the entrance to Galveston Bay until the last few centuries. Settlement ranges from 1.45 feet near the east end of the wall to a mere 0.1 foot near the central portion of the County wall about at 27th Street which was built in 1902-04.

Concurrently with construction of the county sea wall the city of Galveston undertook extensive grade raising in the city behind the wall. This work started in 1903 and continued at intervals through 1948, at which time all of the area within the city except a 10,200-foot section north of Broadway and a narrow strip along the west city limits had been filled. The present grade of the city slopes uniformly from an elevation of 14 feet on Avenue T behind Fort Crockett to 10 feet at Broadway and 8 feet along the channel. The cost to the city for grade raising amounted to about \$6,000,000, of which about \$4,000,000 was received from State taxes remitted to the city for this purpose. The Fort Crockett Military Reservation was filled at the time the sea wall was constructed. The San Jacinto Military Reservation has been filled to a considerable extent with spoil from channel dredging.

The sea wall has not been subjected to a severe test since 1919. The highest storm tide since then was 7.7 feet above mean low tide which occurred in 1942. Four other storms caused tides of between 6.0

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and 7.4 feet at Galveston. The only damage to the sea wall from these storms was loss of beach sand and slight lowering of the riprap at the toe of the wall. The roadway ramps at the south jetty, 6th Street, and 61st Street were usually damaged and there was generally some erosion around the west end of the wall. Repairs consisted of rebuilding the ramps and replacing riprap as required. Data on the cost of maintenance of the sea wall are not available. Normal maintenance other than repair of storm damage has consisted principally of repairing and repaving the roadway on the embankment behind the sea wall.

The sea wall between 10th Street and 53rd Street as originally constructed was located so that there was an appreciable beach, up to 300 feet wide in places, on the seaside of the wall. The storm of 1915 washed away practically all of this beach. Some of the beach materials were returned to the beach within a short period; however, several succeeding cycles of erosion and accretion resulted, in 1934, in lowering the beach and in recession of the shore line until it generally coincided with the toe of the riprap along the sea wall. There was danger that further loss of sand from in front of the sea wall would expose the untreated wooden piling under the sea wall to destruction by teredo.

A cooperative beach erosion control survey, made in 1934 by the Beach Erosion Board, Corps of Engineers, concluded that the sea wall could best be protected and a beach for recreation be provided by the construction of a system of groins from 12th Street to 61st Street. The Board further concluded that a groin system might not be filled by natural action and that artificial replenishment of the beach materials might become necessary. Construction of the proposed groin system was authorized by Congress in 1935, and a system of 13 groins, each 500 feet long and 1,500 feet apart, between 12th Street and 59th Street, was constructed from 1936 to 1939. The groins have accumulated considerable quantities of beach materials, most of which is below mean low tide, and have kept the toe of the sea wall well protected. Excess loss of beach materials during hurricanes has prevented accumulation of sufficient materials to provide a suitable beach for recreation.

The protection that the sea wall afforded the city of Galveston encouraged development of the city. The protected area became densely occupied with houses and at present there is little undeveloped land, protected by the sea wall, available for expansion of the city. Development has taken place toward the southwest beyond the sea wall, despite the danger of destruction by hurricanes. In order to afford protection to this area, Congress in 1950 authorized construction of a 3-mile southwest extension of the Galveston sea wall, similar in design to the existing wall. The riprap at the toe of the wall is 40 feet wide and the embankment behind the wall rises to an elevation of 21 feet at a distance of 155 feet from the face of the wall. The top of the wall is reduced to a width of 3 feet. A section of the proposed wall is shown on figure 3f. The authorization provides that local interests contribute

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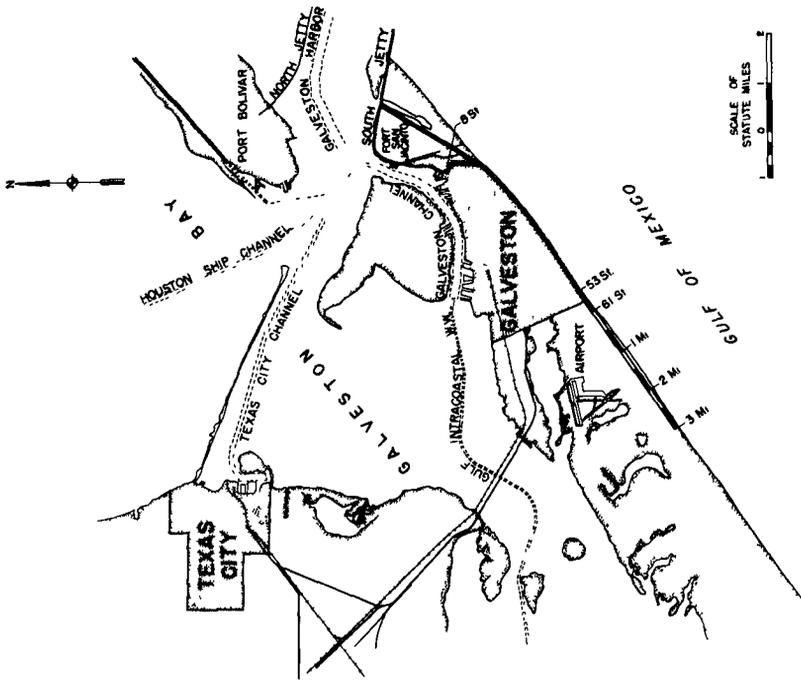


Fig. 7. Galveston Island showing authorized 3-mile west extension of the sea wall.

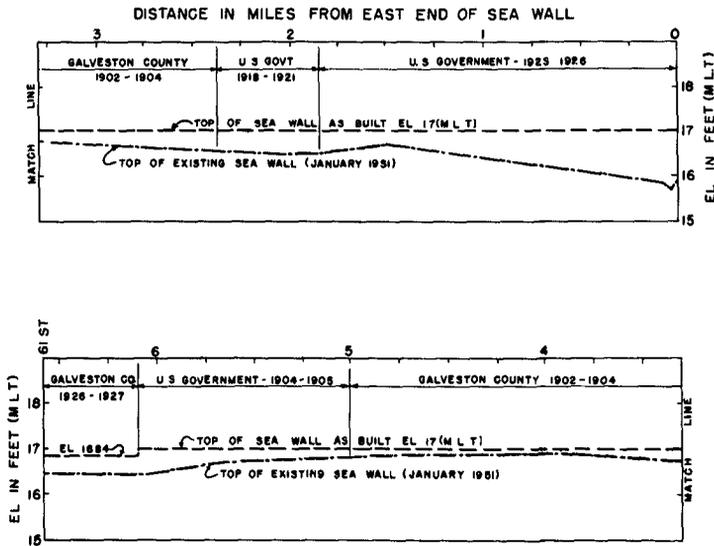


Fig. 6. Profile of the top of the existing sea wall showing settlement.

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\$2,870,000 toward the cost of the project, estimated at about \$9,000,000. The estimated cost is about \$550.00 a linear foot of wall. No Federal funds have been appropriated by Congress; however, Galveston County has contributed its share to the Corps of Engineers and construction of 5,151 feet of the extension is now under way. (Fig. 7).

This culminates the history of the Galveston sea wall.