

COASTAL ENGINEERING

Chapter 18

GULF HURRICANES AND THEIR EFFECTS ON THE TEXAS COAST

Colonel Louis W. Prentiss
Division Engineer, Southwestern Division
Corps of Engineers, Dallas, Texas

The word "hurricane" is derived through the Spanish from a word of the extinct Indian aborigines of Haiti, meaning "evil spirit". I do not know whether the Indians who gave this kind of a disturbance its name are extinct because of the "evil spirit", but I am sure that it is a fitting name. Since the time of Columbus, there are records of hurricanes which have caused destruction and death in the West Indies and areas of Central and North America.

ORIGIN OF HURRICANES

The formation of these hurricanes in the northern hemisphere begins when air moves into a local low pressure area and the rotation of the earth directs the wind in a counter-clockwise spiral toward the center. As these disturbances expand into a tropical cyclone, they grow in size and velocity around the center, or "eye", which remains a relatively calm area of very low pressure.

The cyclone has two distinct movements - this rotary movement within the mass, and a progressive movement of the entire storm mass. These two movements are combined in much the same way as a rapidly spinning top which changes its location slowly.

BREEDING GROUNDS

Some of the hurricanes reaching the Texas Gulf Coast form in the region of the Atlantic Ocean lying generally north of the equator and south of the Cape Verde Islands between the northeast and southeast trade winds, and some form within the Caribbean Sea and the Gulf of Mexico. These regions have the supply of warm water vapors essential to the formation of hurricanes.

PATHS OF TRAVEL

The general pattern of hurricane paths runs westward or north-westward from the Atlantic Ocean into the Caribbean Sea and the Gulf of Mexico with a slow curving to the north which becomes more and more pronounced as higher latitudes are reached until the direction of travel is almost reversed and the storm either dissipates or heads

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back into the Atlantic Ocean on a northeasterly course. This general tendency, however, has a great many variations.

SEASONAL VARIATIONS

Hurricanes have occurred in the Gulf of Mexico only during the 5 month period from June through October. There is a decided variation in the movement of hurricanes during this 5 month period. Early in the season nearly all of them move from the western part of the Caribbean Sea into the Gulf of Mexico, crossing the coast-line into Mexico or the Gulf States. During August and September, and less frequently in July and October, hurricanes develop on the Atlantic Ocean south of the Cape Verde Islands and move in a westerly direction across the Atlantic, some of them reaching the coasts of the southeastern states before they curve to the northward and northeastward. Late in the season they again originate largely in the western Caribbean Sea and follow much the same course as storms from that region in June, except that they are more likely to turn northward and northeastward in lower latitudes, sweeping out over Florida or the Greater Antilles.

ABNORMAL TRACKS

In addition to these general variations there are so many exceptions that the track of a single storm may bear little relation to the general pattern. An example is the hurricane of October 30 - November 8, 1935, known as the "Yankee Hurricane", which formed over the Atlantic Ocean some 300 miles east of Bermuda. After approaching North Carolina, it turned abruptly toward the Bahamas, then veered off to cross the tip of Florida, describing a giant oval in the Gulf before dying out back on Florida's west coast.

In early September of this year the large Hurricane EASY was headed directly toward the island of Bermuda when the close approach of the Hurricane FOX brought about a positive change in course, causing EASY to miss Bermuda.

OCCURRENCES AND FREQUENCY

RECORDED OCCURRENCES

In the last 66 years, there have been 35 hurricanes that have affected the Texas coast, distributed as follows: June - 6, July - 6, August - 13, September - 7, October - 3.

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Considering these 35 hurricanes actually recorded since 1886, it appears that some part or parts of the Texas coast will be struck by a hurricane on an average of about once every 2 years; however, cycles in frequency have brought more than half of the storms in a fourth of the time, leaving 39 of the 66 years hurricane free. Four hurricanes struck this coast in 1886, and in 5 other years 2 occurred.

The number of hurricanes experienced at each of six Texas ports is reasonably close, those to the north showing a somewhat higher rate. Port Lavaca, along the central coast, has experienced 2 less storms than any of the other 5 ports. The table below shows the number of times hurricane centers have passed within 50 miles of these 6 ports. The totals in this table exceed 35, since several hurricanes have affected 2 or more ports; however, most of those have approached the coast-line about perpendicularly.

<u>Seaport areas affected</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>October</u>	<u>Totals</u>
Brownsville	2	-	3	3	1	9
Corpus Christi	4	2	2	1	-	9
Port Lavaca	2	1	4	1	-	7
Freeport	1	3	4	2	1	11
Galveston	1	3	4	2	2	12
Port Arthur	1	2	5	1	1	10

Texas seaports may, on the average, expect to be affected by a hurricane about once in every 7 years; nevertheless, during the 66 years of record both the Port Arthur and Port Lavaca areas have enjoyed 19 successive hurricane seasons in which none were experienced; Galveston has had 18 years, Freeport 16 years, Corpus Christi 15 years, and Brownsville 14 years.

HISTORICAL OCCURRENCES

Information on the frequency of hurricanes before 1886 is fragmentary; however, there are records of 5 hurricanes in the last 5 years of the 15th century, 27 in the 16th century, 39 in the 17th century, 158 in the 18th century, 426 in the 19th century, and 166 for the 20th century through 1944. Many factors are cited as affecting the reliability of these figures.

There are accounts of severe gales in Galveston Bay in September 1766, and in September of 1818 four of Jean LaFitte's privateering vessels were washed ashore on Galveston Island. Eighteen other hurricanes are known to have struck the Texas coast from that time through 1885, some of them of very severe intensity.

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HURRICANE MAGNITUDES

Winds with velocities of 75 miles per hour or higher are considered to be of hurricane force by the Beaufort Scale, established in 1805 and still in use. In general, Mr. Charles L. Mitchell of the U.S. Weather Bureau has classified tropical cyclones as being of hurricane intensity when they have a central atmospheric pressure of 29.00 inches or lower and are accompanied by winds near the center of more than 60 miles per hour. "Great hurricanes" are those in which the central pressure usually falls to or below 28.00 inches with the path of great damage about 50 miles wide. Some of the great hurricanes may cause damage in paths 600 miles wide. Only about one in ten hurricanes can be classed as "great hurricanes".

WIND VELOCITIES

There is good reason to believe that winds of an average rate of more than 150 miles per hour are sustained for five minutes and that gusts may reach as high as 250 miles per hour in the more violent storms. It appears that few, if any, hurricanes striking the Texas coast have reached these velocities. The extreme velocities of the 1900 and 1915 Galveston hurricanes were estimated at 120 miles per hour.

Since the atmospheric whirl north of the equator is counterclockwise, there is added to the circular movement of the wind on the right-hand side of the storm, facing in the direction of its progress, the velocity of the general movement of the storm mass. Conversely, the winds on the left-hand side are decreased because of this action. The average velocities in the rear half are greater than the front half, making the right rear quadrant the most damaging.

STORM TIDES

The swells and waves generated by a hurricane travel directly forward from the right front segment of the storm at speeds calculated to be as much as 40 to 50 miles per hour and have been observed to precede the center of Gulf hurricanes by 600 miles. These rises, frequently referred to as "tidal waves", are not waves in any sense of the term, but are storm tides that exceed the undisturbed sea levels.

Both the topography of the Texas coast and low gravitational tides keep storm tides at or below 15 feet MSL as compared with a high of around 25 feet in the New England area.

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DURATION

The average observed life of tropical storms in the Atlantic, Caribbean, and Gulf waters is about 9.5 days. Because many storms are probably unobserved in the early and later periods, it is likely that the average life is actually somewhat longer. August hurricanes have the longest observed average life of about 12 days; July and November storms have the shortest life, about 8 days. Several tropical storms have been tracked for 3 to 4 weeks and one, the 1900 Galveston hurricane, was tracked from the Mid-Atlantic west-northwestward to the Texas coast, thence north and northeastward across the United States to the Great Lakes, out over Newfoundland, back into the Atlantic Ocean, past Iceland and ultimately eastward into Siberia.

A hurricane with a diameter of 150 miles and a forward movement of 12 miles per hour would subject a specific locality to hurricane winds for at least 12 hours and to gusty squalls for something like 36 hours or longer.

PRECIPITATION

Heavy rain occurs in the forward half of the storm mass, considerably in advance of the center but very little falls in the rear half.

Heavy rainfall reflects radar impulses and may be satisfactorily observed through the use of specially designed radar equipment. Any unevenness in the downpours of the forward half of a hurricane, because of the rapid circular movement within the storm, appears on the radar screen as arcs from which the storm center can be determined with reasonable reliability. The Dow Chemical Company, as an adjunct to Weather Bureau activities, established at Freeport, Texas, a radar system to assist in minimizing hurricane damage to its extensive facilities located there. We are indebted to that company for the excellent motion picture record of their radar work during the approach of the 1949 hurricane to Freeport.

DESTRUCTIVE EFFECTS

DAMAGES

Perhaps the most destructive hurricanes in modern times have struck Calcutta, India. The 1864 storm drowned 50,000 persons and resulted in death to an additional 30,000 from disease. About 200,000 persons died as a result of the 1876 hurricane, approximately one-half of them drowning. Within the area of travel of

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our Texas coast hurricanes, the "Great Hurricane" of October 1780 devastated the island of Barbados, sank an English fleet off Santa Lucia and killed 6,000 people on that island; sank 40 vessels in a French convoy off Martinique with a loss of 4,000 soldiers, killed 9,000 people on Martinique and left a path of devastation across other West Indian islands. The two islands of Martinique and Santa Lucia, where 15,000 people were killed, have an area of only about 600 square miles.

Estimates of property damage are not available from these storms; however, estimates range from \$250 million to \$330 million for the losses incurred in the September 1938 hurricane which hit the Long Island-New England area, killing about 600 people.

Over 6,600 lives have been lost and at least \$136 million damage done in the Texas coast area since 1875, considering only the readily available information on the worst hurricanes, about 9 in all, during the period.

1900 GALVESTON HURRICANE

All of the destructive characteristics of hurricanes were brought to bear on Galveston during the September 8, 1900 storm. By five o'clock in the morning the tide was 4.5 feet above normal and had covered the lower sections of the city; by five p.m. a 9-foot tide had put water over the highest streets. The sloping beach, which under normal tides helped to break up the waves as they approached shore, no longer gave protection to the island, and when the maximum tide of 14.5 feet MSL came in the city's buildings were subjected to the full force of waves well over 20 feet high. Not only the buildings, but the land on which they were built, disappeared along a strip a block or more wide. Destruction of over 2,600 homes in a suburban area of 1,500 acres was complete.

Many of the total of 3,600 houses demolished were of sufficient structural strength to withstand the highest winds, but their foundations were undermined and they were battered with terrific force by the debris of less well built houses and other wreckage. In some places, however, debris gathered to form a protective barrier and was probably instrumental in saving other buildings from complete destruction. A large ocean-going steamer was torn from its moorings and carried several miles inland, requiring the construction of a canal to get it back to deep water.

More than 6,000 of the 38,000 population lost their lives and it is probable that the loss would have been much higher except

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for early warnings which enabled thousands to leave the island before the highway and railway bridges to the mainland were submerged about noon, at least eight hours before the center of the storm arrived. Although the property damage of around \$25 million has been greatly exceeded in more recent hurricanes, the loss of human lives was far greater than in any other North American hurricane.

In 1915 Galveston was hit again by a great hurricane; however, the developed part of the town had been raised in elevation and five miles of sea-wall along the Gulf shore had been constructed by Galveston County and the Corps of Engineers. Only 12 lives were lost and property damage was held to \$4½ million. There was extensive damage outside of Galveston, largely in the Freeport area, and the hurricane resulted in a total loss of 275 lives and property estimated at \$50 million. This storm was of approximately equal intensity but of longer duration. It had a maximum storm tide of 12.7 feet MSL, 1.8 feet lower than the 1900 hurricane.

The difference between these and other Texas coast hurricanes is largely a matter of degree and extent of damages.

SHORE-LINE CHANGES

There have been evidences, ever since the settlement of the Texas Gulf Coast, of shore-line changes both above and below the water level. Under usual weather conditions these changes are so gradual that they become apparent only through observation over a period of several years. Changes are more obvious in the passes to the mainland through the chain of islands which makes up 4/5's of the 400-mile Texas coast-line.

Many times these passes are opened up by hurricanes only to be shoaled again in periods of normal weather. The 1949 hurricane cut 5 small openings in the Matagorda Peninsula between Port O'Connor and the Colorado River, and cut 2 small openings between the Colorado River and Brown Cedar Cut, but all of these are closing rapidly.

The Corpus Christi Pass between Mustang and Padre Islands is usually washed open by hurricanes, only to shoal up gradually afterwards.

A pass at Murdocks Landing was opened up across Padre Island by the 1933 hurricane. For 4 consecutive years the State Game and

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Fish Commission dredged it, but it closed again within 4 months each time. In August 1945 local fishermen reopened it and a hurricane a few weeks later enlarged it; however, normal weather closed the pass once more.

None of the major passes are known to have been shoaled up by hurricanes since the jetties were built, although the jetties themselves have been damaged by the currents and waves which wash out stones and cause settlement or breaching through undermining and erosion. Under normal conditions all these major passes require periodic maintenance dredging.

One of the reasons for the scouring out of passes during disturbances is that the storm tides fill the bays and when the Gulf level recedes an appreciable head is left in the bays. The current from the bays to the Gulf, created by this head, is rapid enough to carry heavy loads of material from the channels.

On the other hand, some passes may be closed by hurricanes if the force, direction, point of attack and local conditions are favorable to this action. The Cedar Bayou Pass across Matagorda Island northeast of Rockport is fairly permanent, but was closed by the 1929 hurricane.

Some shoaling, but not enough to interrupt navigation, occurred in the Galveston Channel during the 1915 hurricane. The dimensions of the reach of the Gulf Intracoastal Waterway in the Matagorda and San Antonio Bays were reduced from 9 ft. x 100 ft. to about 6 ft. x 60 ft. by the 1942 hurricane when the material in Gulf-side spoil areas was carried back into the channel.

PROTECTIVE WORKS

For well over half of a century, protective works of various kinds have been undertaken by local interests and the Corps of Engineers. As an example, there are the jetties, from one to six miles in length, which have been built to keep open the five major passes through the coastal islands.

Some of the principal problems and a good part of the protective construction are found at Galveston, the only major Texas port which fronts directly on the Gulf. The construction of the south jetty in the period 1887-1897 reversed a tendency toward erosion and brought about an advance of about a mile in the shoreline of the east end. Further west along the Gulf side there was erosion up to about 300 feet; however, following construction of

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the sea-wall, after the 1900 hurricane, the beach built out 300 feet wide in places and it was possible to drive outside the wall for its full length. The 1915 storm scoured out the beach to a minimum depth of four feet and built up a bar parallel to the shore-line some 600 to 800 feet off shore. The natural accretion of normal weather periods moved the bar back into the shore-line. Various hurricanes up through 1942 threatened to scour out channels across low places in the island which would have seriously damaged the city, its harbor, its rail and highway outlets to the mainland, and its water supply lines. Additional protective works were provided and there is at this time a sea-wall extension job in progress.

In a following chapter a history of the Galveston Sea-wall by Mr. A. B. Davis of the Galveston District, Corps of Engineers is presented. I would like to point out the cooperative manner in which local interests and the Corps of Engineers are working on these improvements. We made recommendations to Congress for a sea-wall extension project in which both local and Federal governments were to participate. In view of current conditions, Congress made no appropriation to carry out the Federal participation at this time. Galveston County furnished its share of funds, enabling the Corps of Engineers to go ahead with construction of another mile of sea-wall.

REFERENCE

Tannehill, I.R. (1944). Hurricanes; Princeton University Press, Princeton, New Jersey, 5th edition, 269 p.