HURRICANES on the Texas Coast

TEXAS A&M UNIVERSITY • A SEA GRANT COLLEGE

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Foreword

When hurricanes strike the Texas coast and travel inland, they affect the lives of thousands and possibly millions of Texans. The destructive ferocity of these great storms is almost beyond comprehension. In one 24-hour period a hurricane can generate heat energy equal to 400 20-megaton hydrogen bombs and can circulate almost one trillion tons of air carrying 17 billion tons of water vapor.

Besides the obvious physical damages due to storm surge, strong winds, and high tides, which usually are restricted to areas near the coast, there are damages from large amounts of rainfall that may extend inland for hundreds of miles. This rainfall sometimes helps to relieve drought but more often results in widespread flooding, harmful erosion, and ruined crops.

Since preparation is the key to survival during a hurricane, this booklet has been designed to help Texas coastal residents understand, plan for, and recover from the devastating effects of these storms. Originally published in March 1975 as three volumes, Hurricanes on the Texas Coast was written and revised by Texas A&M University's Center for Applied Geosciences with assistance from the University's Sea Grant Program.

Acknowledgments

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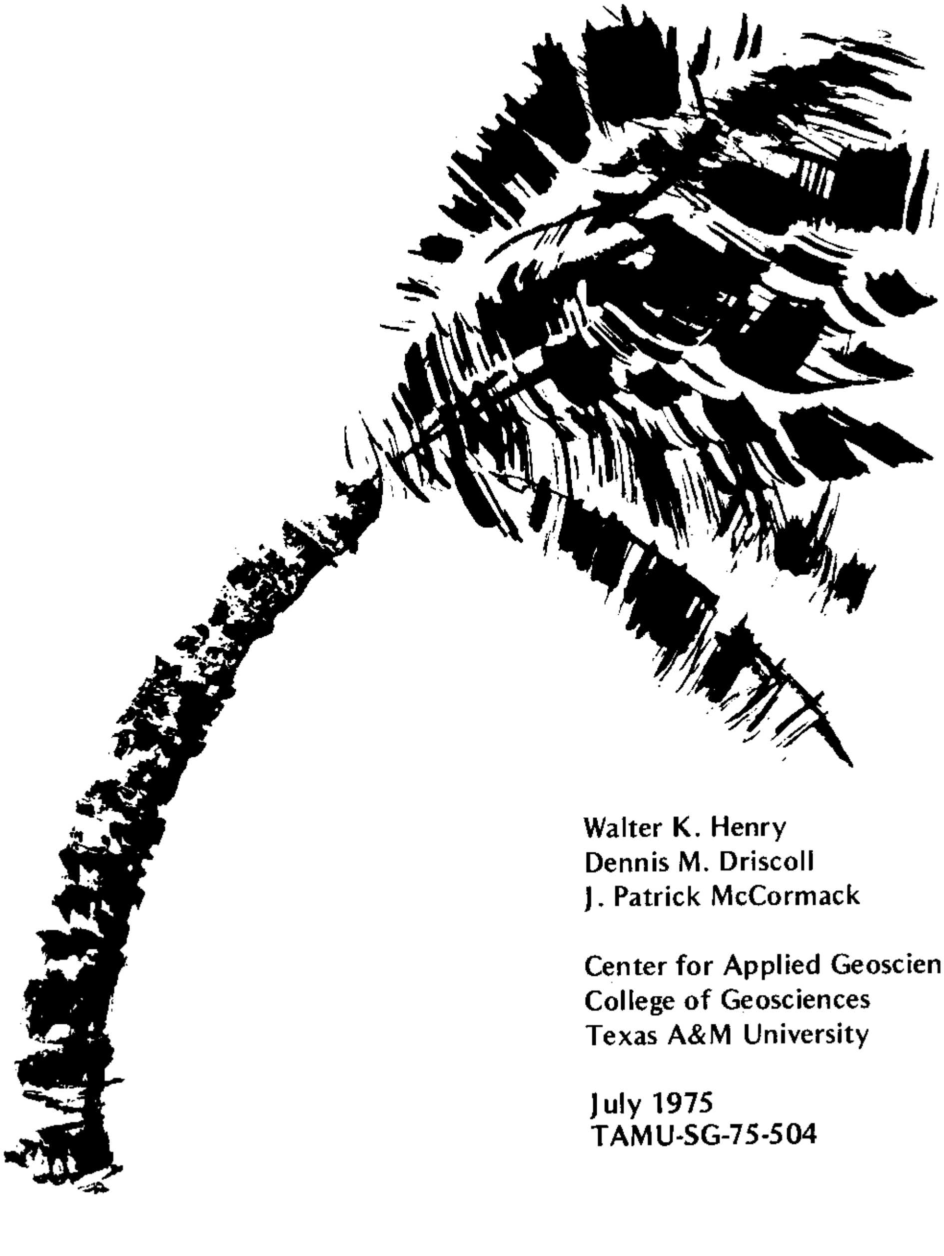
HURRICANES on the Texas Coast



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Up to five copies of *Hurricanes on the Texas Coast* will be sent free to a single address. Orders for between five and fifty will be filled at $1.00 each. On orders for more than fifty copies, the price is $.75 and the publisher reserves the right to limit quantities.

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Description and Climatology

THE GREATEST STORM ON EARTH

The hurricane, rightfully called "the greatest storm on earth," is one form of tropical cyclone -- an immense, cyclonically (counterclockwise) swirling storm system, covering thousands, sometimes hundreds of thousands of square miles. Peak wind gusts near the center of the hurricane may exceed 200 m.p.h. Due to its size, intensity, and duration, the hurricane is the most destructive weather phenomenon known to man.

The English word "hurricane" probably comes from the Spanish word "Huracan," which was derived from either Hunraken, the Mayan storm god, or Hurakan, the Quiche god of thunder and lightning. The word hurricane designates large cyclonic storms occurring in the western hemisphere. Similar storms are known as typhoons in the western Pacific, cyclones in the Indian Ocean, and Willy-Willys near Australia.

A glossary of hurricane terms is presented in Appendix I for convenient reference.

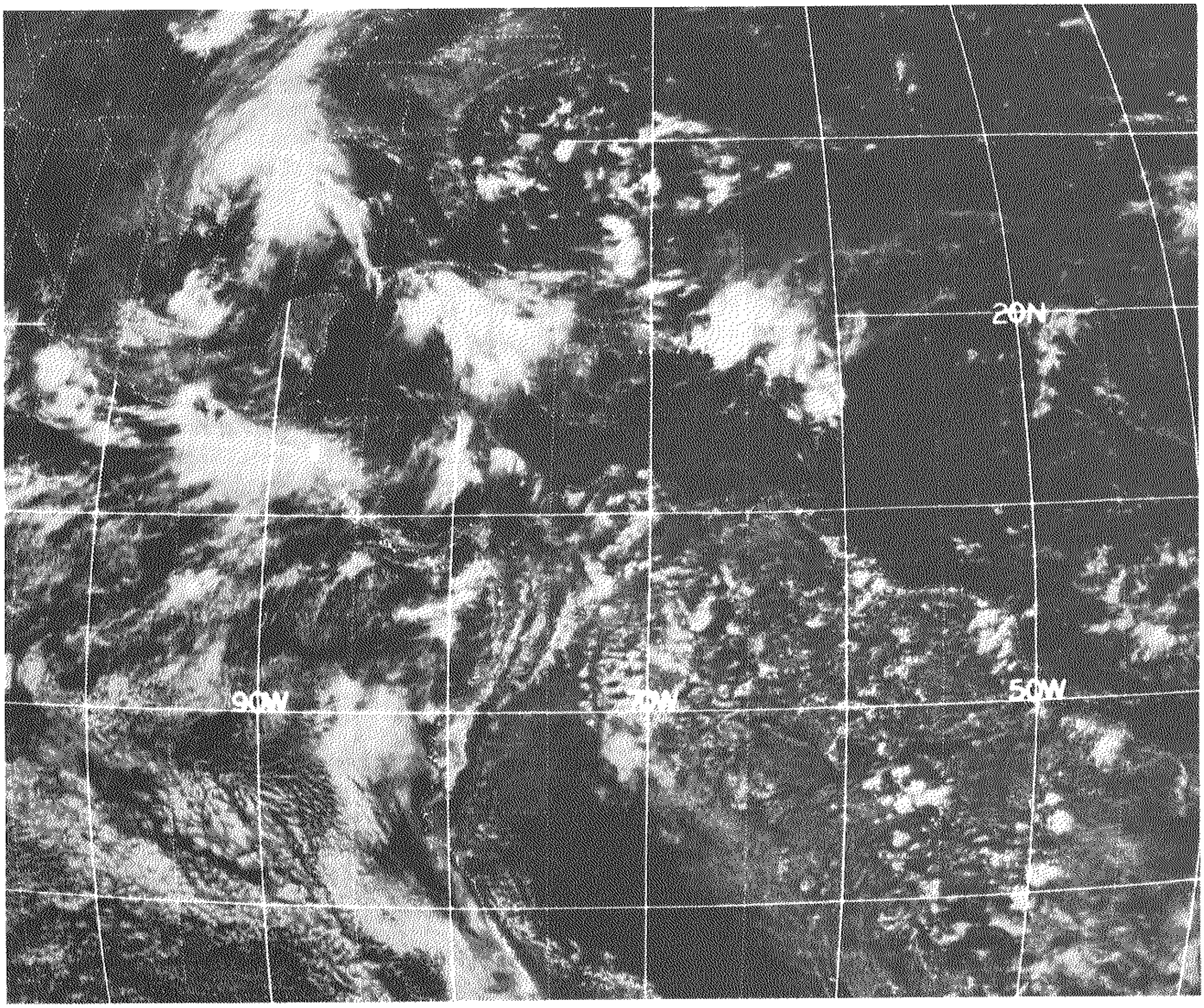


Fig. 1. A satellite view of North America, taken on September 4, 1973, at 1649 Greenwich Mean Time by ATS3. Tropical Storm Delia is located on the eastern coast of Texas and Tropical Storm Christine is near Puerto Rico. Photo courtesy of NOAA-NESS.

Fig. 2. The remains of a building after the walls were collapsed by winds of Hurricane Celia. Photo courtesy of the Texas Highway Department.

DESCRIPTION OF THE HURRICANE

Tropical cyclones form and grow over warm water. Those which approach the Texas coast form over the Gulf of Mexico, the Caribbean Sea, or the tropical areas of the North Atlantic Ocean. These areas are under the influence of the trade winds, which are on the south side of the Azores-Bermuda High (see Fig. 3). On occasion a low pressure area forms in the broad flow of the trade winds, and a few of these lows develop into tropical cyclones.

When a low intensifies, winds blow counterclockwise around it, an extensive cloud layer forms, and rain showers develop. If meteorological conditions are favorable, a tropical cyclone may develop through the stages of tropical depression, tropical storm, hurricane, and even to an extreme hurricane.

It is important to realize that each hurricane is different. The description that follows is general and might not apply in all aspects to a specific hurricane.

The eye of a hurricane is the feature which makes it unique from cyclonic storms of the more northern latitudes. The eye is a somewhat circular area of comparatively light winds. It is usually rain-free and may vary from four to more than 40 miles in diameter. Diameters of 12 to 20 miles are common.

As can be seen in Fig. 4, hurricane winds are not symmetrical about the eye. When facing the direction in which the hurricane is moving, the strongest winds will usually be to the right of the eye and may approach a speed of 200 m.p.h. The radius of hurricane force winds may be 50 miles, but it varies from ten miles in small hurricanes to a hundred miles in larger storms. The strength of the wind decreases in relation to the distance from the eye as shown in Fig. 4. At 200 miles from the eye the winds may be gale force and gusty.

Rainfall forms in cumulonimbus clouds. The clouds' location with respect to the eye is shown schematically in Fig. 5. Rainfall is showery and quite variable. As the rain clouds move past, rain starts and stops. Rain clouds spin around the storm like a large pinwheel while the center of the pinwheel also is moving. Thus, the movement of any one shower is difficult to illustrate. Rain is not uniformly distributed about the eye, with most falling in the area of maximum winds. Rain squalls may extend out from the eye for 20 to 200 miles.

Low scud clouds accompany areas of rain. Cirrus clouds cover the cyclone and extend outward from it. Prior to the use of radar and aircraft reconnaissance, cirrus clouds were the first sign that a storm was approaching. The satellite photo, Fig. 6, shows cloud cover, but rain bands are partially hidden by cirrus clouds. An example of a shower area is shown in the radar picture, Fig. 7.

Hurricanes cause destruction in several ways:

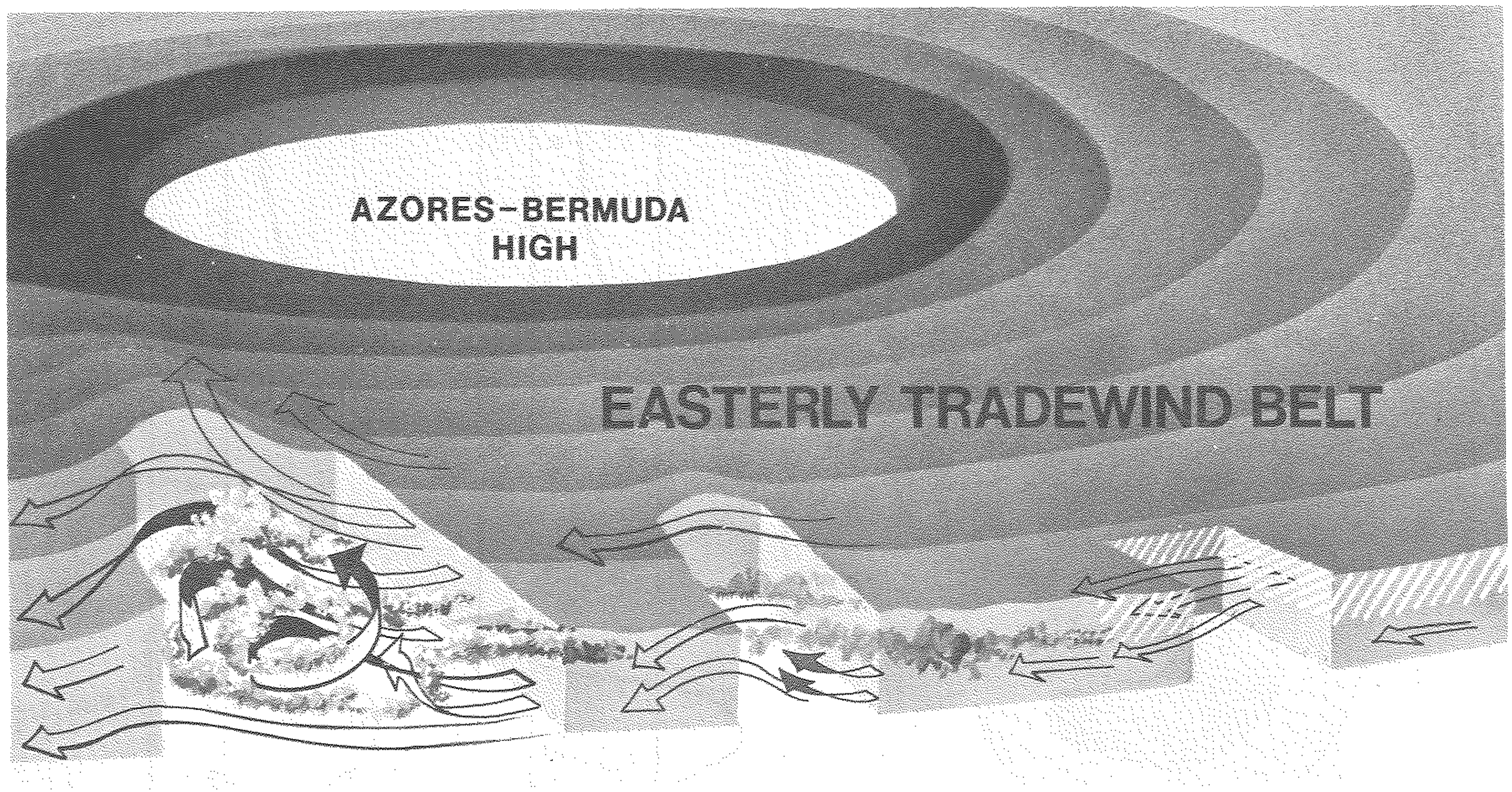
Strong winds may destroy some structures, as shown in Fig. 2.

Storm surge can level structures and float houses and boats from their foundations and moorings. Figs. 8 and 9 show the aftermath of the storm surge.

Heavy rains may cause flooding in the flood plains.

Tornadoes are often associated with hurricanes.

Residual problems, such as displacement of snakes from their usual habitats, disruption of communications, and destruction of utilities, may arise after the passage of a hurricane. Public health measures must be taken to prevent illness and epidemics.



D.

Increased convection, and the pumping action of high altitude winds, may cause the easterly wave to deepen further, becoming strong from the surface to 15,000 feet or more. Atmospheric pressure becomes an isolated depression--and the trade winds begin to turn in on themselves, forming a weak cyclonic circulation about the center of low pressure. This circulation may intensify, pressure may continue to drop, the winds spiralling around the center of low pressure may accelerate--the disturbance may become a severe tropical cyclone.

C.

Intensified convection may be accompanied by a trough of low pressure in the trade wind belt. This poorly developed easterly wave is weak at the surface, stronger near 15,000 feet, weak at high altitude. Thunderstorms may develop behind the wave as the air is raised and shunted northward; ahead of the wave, air is subsiding, weather is fine. A wave of this intensity may travel for miles without appreciable change.

B.

As the inversion layer weakens to the west, and as the lower layers become increasingly warm and moist, convection intensifies. Clouds form, and begin to rise to greater altitudes.

A.

The characteristic vertical structure of the easterly trade wind belt, in which a relatively shallow layer of moist air is overlain by a deeper layer of subsiding warm dry air. The two layers are separated by a temperature "inversion." Moisture from the sea evaporates into the lower atmosphere but cannot rise above the inversion. However, the moisture charge received by the lower layers contains the latent heat energy that once released by condensation and convection to high levels, can drive a tropical disturbance.

Fig. 3. Schematic development of a tropical cyclone in an easterly wave located to the south of the trade wind belt. Adapted and modified from Hurricane, the Greatest Storm on Earth, *by NOAA, see references.*

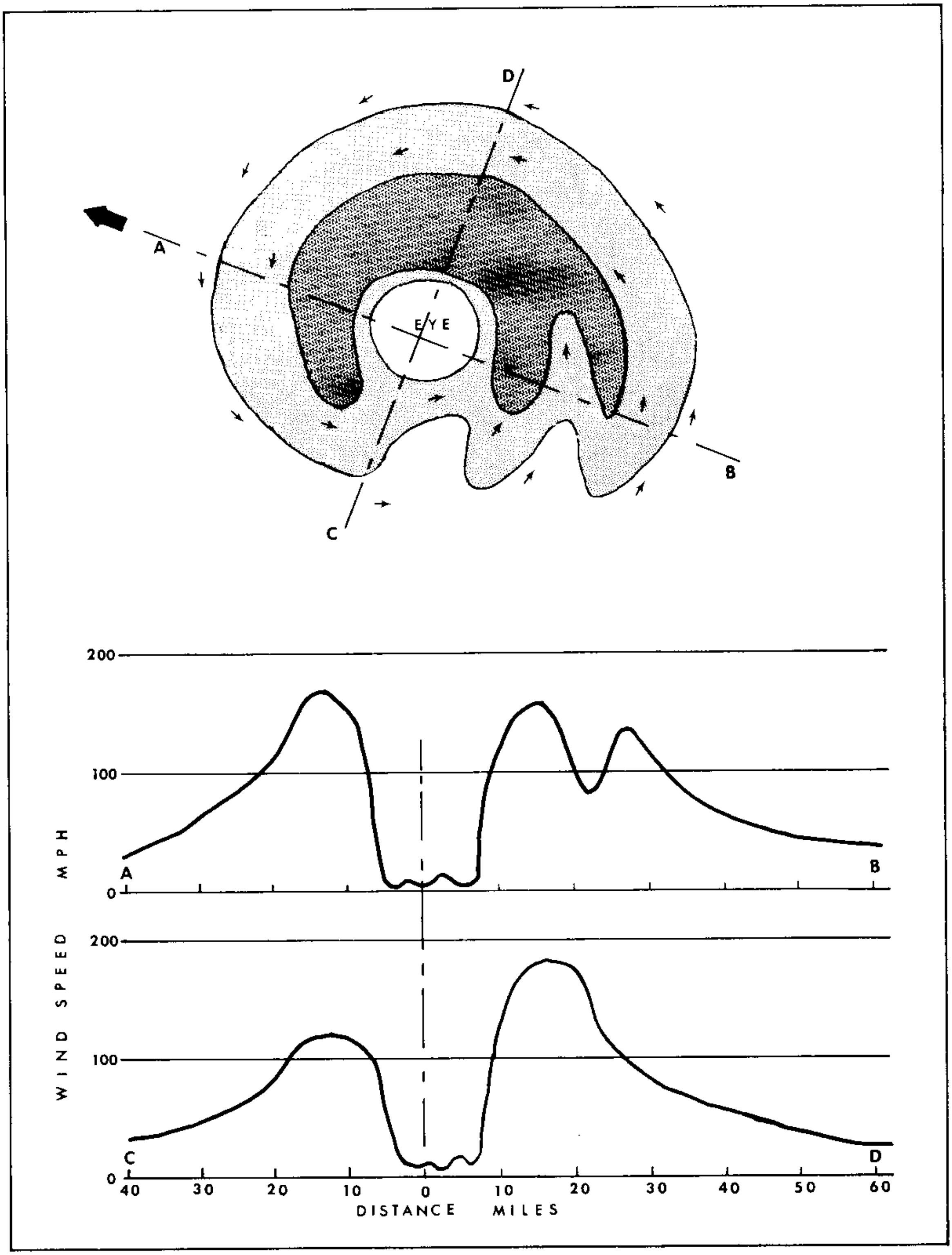


Fig. 4. A schematic representation of the wind distribution around the eye of an extreme hurricane. The large arrow pointing to the upper left indicates the direction of the hurricane movement. The smaller arrows indicate the wind direction within the hurricane. The light hatching indicates the area of hurricane strength winds. The darker hatching indicates the area of winds greater than 136 miles per hour. The graphs below indicate the variation of wind strength along the lines A-B and C-D.

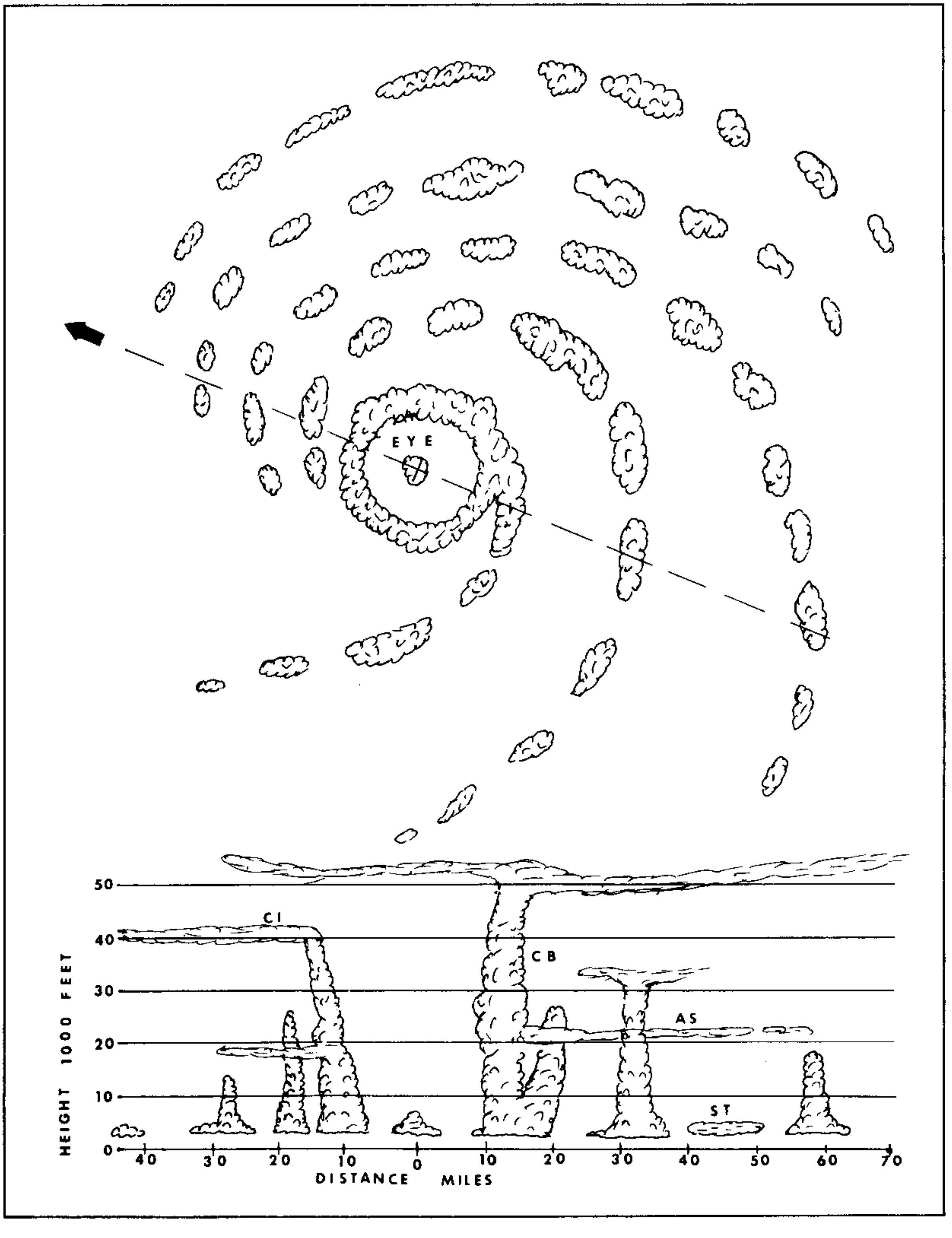


Fig. 5. A schematic plane view and side view of the rain clouds of the same generalized hurricane in Fig. 4. The heavy arrow indicates the direction of the hurricane movement. The rain clouds are arranged in spiral bands. Clouds along cross sections about the direction of movement are indicated in the side view. Cloud types shown are cumulonimbus (CB), altostratus (AS), stratus (ST), and cirrus (CI). Cirrus clouds cover the entire storm, and low stratus (scud) clouds hide the upper cloud structure from the ground.

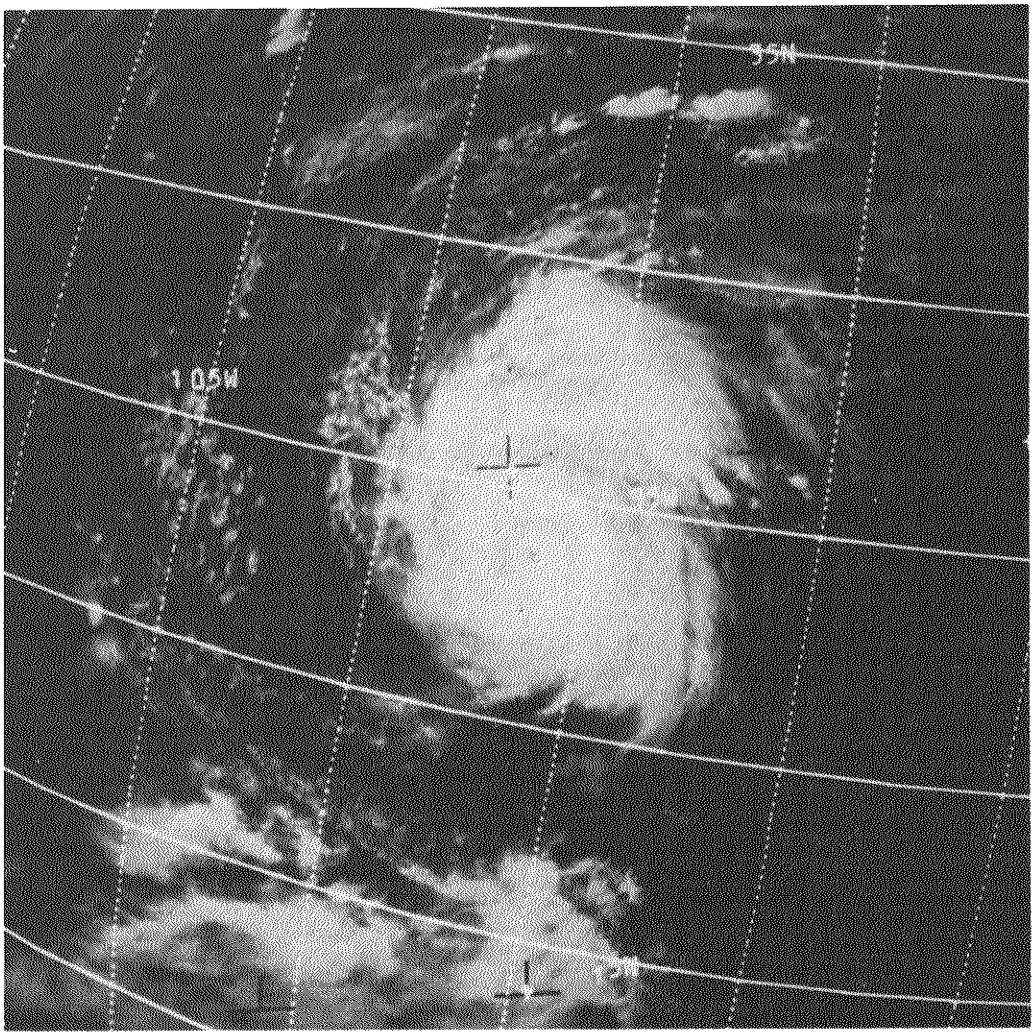


Fig. 6. A satellite picture of Hurricane Beulah. The eye is easy to identify, just below the +. Note that the eye is not in the center of the cloud mass. The spiral bands of clouds can be seen around the eye. Photo courtesy of the National Hurricane Center.

A BRIEF RESUMÉ OF A FEW TEXAS HURRICANES

In one respect, hurricanes are like snowflakes--no two are exactly alike. Hurricanes can form anywhere from the Cape Verde Islands off the west coast of Africa to about 150 miles off the coast of Texas. Those affecting Texas can form anytime from June through October. Other characteristics, such as rainfall distribution, tornado occurrence, storm surge, and wind intensities, also are extremely variable.

The costliest hurricane (in terms of lives lost) ever to hit the Texas coast was the Great Galveston Hurricane of September 8-10, 1900. More than 3,600 homes were *completely* razed as storm surge tides of 15 to 20 feet swept the first two to five blocks of the east, south, and west sections of the city. People were advised to leave the island prior to hurricane landfall, and an estimated 12,000 people did so. Nevertheless, an estimated 6,000-8,000 people died, making this the worst weather disaster in U.S. history. Only 10 to 15 percent of the people who remained on the island during the storm survived.

On September 16, 1875 a hurricane hit Indianola, Texas. The storm surge carried away three-fourths of the town and killed 176 people. Eleven years later, on August 20, 1886, Indianola was struck again. This time the storm surge carried away or left uninhabitable *every* house in the town. Indianola was never rebuilt and today the area is a state park. The Indianola experience clearly illustrates the destruction due to storm surges.

Hurricane Celia, August 2-5, 1970, destroyed an estimated $500 million worth of property and became the costliest hurricane to strike the Texas coast in terms of property damage. *Weather Wise,* a publication of the American Meteorological Society, describes some of Celia's unique characteristics. First, nearly all damage resulted from wind (Fig. 10) and not flooding or storm surge. Second, the highest winds occurred in the rear lefthand quadrant rather than in the right front quadrant as would be expected and came in streaks spaced about 1.5 miles apart. Between these streaks almost no damage resulted, even to the frailest of structures. Third, Celia intensified explosively just prior to landfall.

The heaviest rains from Celia amounted to only 6.50 inches at Aransas Pass and 6.38 inches at Corpus Christi. The towns of Pearsall and Jourdanton, located just 30 to 40 miles north of the eye of the hurricane, experienced no rainfall at all. The highest storm surges occurred at Port Aransas Beach and Port Aransas Jetty and measured only 9.2 and 9.0 feet above mean sea level, respectively.

Celia demonstrated two categories of wind damage that may accompany an extreme hurricane. First, many buildings collapsed due to pressure from rampaging, rain-laden winds. The pressure exerted on a surface increases as a function of the *square* of the wind speed. This means that buildings which can withstand winds of 60 m.p.h. may buckle under winds of 180 m.p.h. because the pressure on their surfaces has increased by a factor of 9. Second, on the lee side of large buildings the dynamic effect of the wind tends to create a partial vacuum. The force due to this vacuum may be strong enough to cause windows to be blown outward. Wind entering the building from the windward side augments this pressure difference and increases the possibility of windows being blown outward. A person taking shelter behind a large building could be showered with falling glass. Some high-rise buildings in Corpus Christi lost their windows and doors during Celia because of this phenomenon.

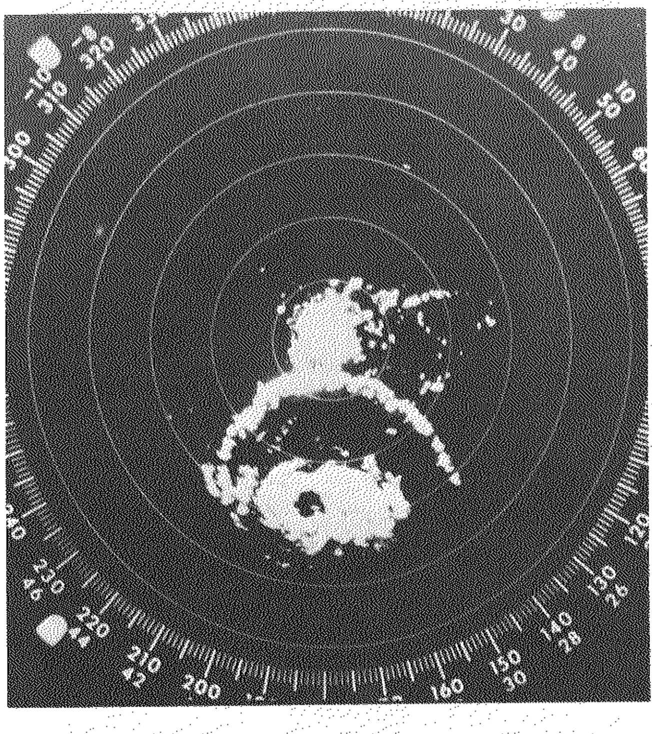


Fig. 7. A radar picture of Celia taken from the Galveston radar, 1245 Greenwich Mean Time, August 3, 1970. Celia was not a rainy hurricane, but the spiral bands of rain clouds do show. The eye is the black hole below the center of the radar picture, between the second and third rings. Photo courtesy of the National Hurricane Center.

Fig. 8. Boat carried inland by the storm surge of Hurricane Carla. Photo courtesy of the Texas Highway Department.

Beulah was another unique Texas hurricane. Not only did she drench the state with the greatest amounts of rainfall, but she also spawned more tornadoes (more than 100) than any hurricane on record. Almost the entire area from Matagorda Bay northwestward to San Antonio and southward to Laredo received at least 10 inches of rain between the 19th and the 23rd of September 1967. This was due partially to her unique track, first moving northward, then recurving southwestward and entering Mexico south of Laredo. Many areas received deluges in excess of 20 inches, and a few areas were inundated with up to 30 inches of rain. Many stations received more rain in four days than they normally would receive in a year.

These torrential rains set off major flooding of every river and stream south of San Antonio. The San Antonio river set new flood records when it crested at 18.4 feet above its flood stage of 35.0 feet. The Nueces River crested at 46 feet, 2 feet above its previous all-time high. The Lavaca River crested at 5.2 feet above its flood stage of 21.0 feet. The Navidad River, which also has a flood stage of 21.0 feet near the town of Ganado, crested at 31.9 feet. Much to the chagrin of local residents, oily residues carried from oil fields by flood waters were deposited on buildings, thus leaving distinctive high water marks.

Beulah's more than 100 tornadoes broke Hurricane Carla's record of 26 in September 1961. Usually, tornadoes produced by hurricanes have a diameter and ground path length of about half the magnitude of tornadoes formed on the Great Plains. The reduced magnitude of these hurricane-associated twisters could be one of the reasons why only five people died due to Beulah's tornadoes. Beulah's winds achieved hurricane force but weakened after landfall so that her heaviest rains occured while she was classified as a tropical depression.

Not all hurricanes are as unique as Celia and Beulah. Carla, like most hurricanes which strike the Texas coast, was predictable. But this did not diminish her potential for damage. Carla, an extreme hurricane, ravaged Central Texas from Victoria to Dallas and caused $400 million damage. She continued northward into the Dakotas causing heavy rains. In terms of monetary damage she is second only to Celia. Port Lavaca took the brunt of the storm surge and measured tides 18.5 feet above normal. Rainfall ranged from 2.82 inches at Paris, in East Texas, to a torrential 16.23 inches at the Galveston airport. Carla's maximum winds peaked at an estimated 175 m.p.h.

Carla was the largest hurricane in recorded history to strike Texas, even larger than the Great Galveston Hurricane of 1900. Yet with $400 million damage, only 34 people died during the storm. Mass evacuation of over 250,000 people from the central and upper coastal cities resulted in the low death toll.

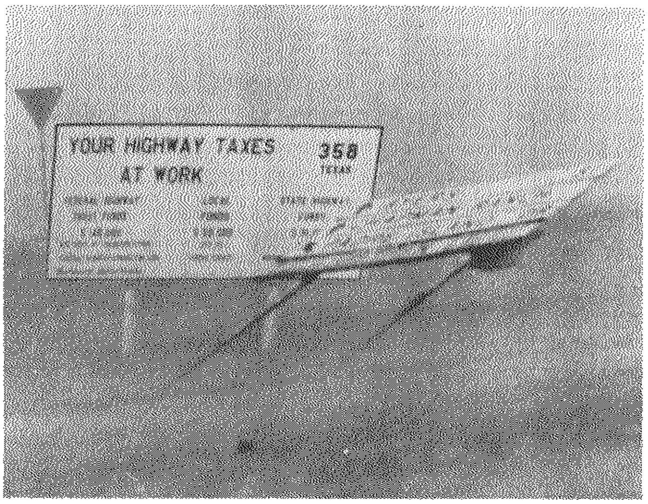


Fig. 10. The wind and rain of Hurricane Celia. Photo courtesy of the Texas Highway Department.

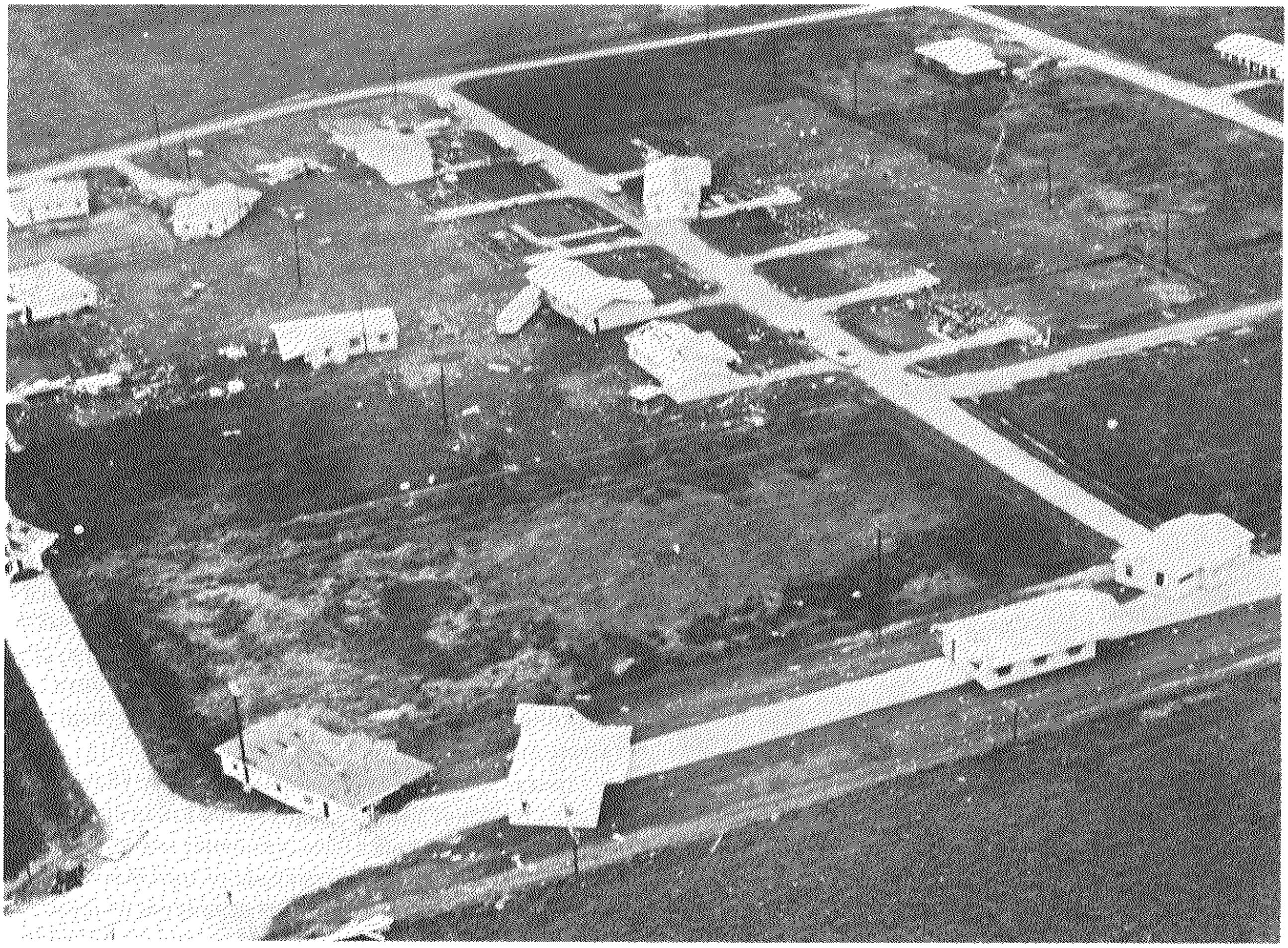


Fig. 9. Houses floated from their foundations by the storm surge and then blown by the wind to new locations at Palacios, Texas, by Hurricane Carla. Photo courtesy of the Texas Parks and Wildlife Department.

CLIMATOLOGICAL DATA

Christopher Columbus encountered the first hurricane reported in the New World during his second voyage. On June 16, 1494, he experienced a violent storm in the vicinity of Santo Domingo, which caused him to declare, "Nothing but the service of God and the extension of the monarchy should induce him to expose himself to such dangers." That same summer he encountered two more violent storms.

During the 104-year period, 1871-1974, 41 hurricanes made landfall in Texas. Thirteen more came close enough to the coast to cause damage. During the same period 25 tropical storms entered the Texas coast and 12 side-swiped the area. For a complete listing of these storms, see Appendix II.

On the average the Texas coast experiences a hurricane every other year and a tropical storm every third year. However, no real uniformity exists because some years have two or more tropical cyclones while others experience none.

Tropical cyclones form only during certain seasons of the year and only in certain regions of the oceans. Since 1871, which is as far back as our records extend, no tropical cyclone has hit the coast of Texas before June or after October. This does not mean that they cannot form or strike Texas during other months, because new weather records are established almost every day. Tropical cyclones have formed as early as February and as late as December, but for Texas the season of vulnerability has been from June through October. Fig. 11 shows the earliest and latest occurrences of tropical cyclones for 50-mile segments of the Texas coast.

The path of the eye differs in each tropical cyclone. Appendix III presents the partial tracks of cyclones entering Texas or coming close to Texas for the years 1871 to 1974. A hurricane tracking chart is presented in Appendix XIII for your use in recording movement of hurricanes.

WHAT'S THE PROBABILITY?

On the average, one tropical storm or one hurricane occurs every year. However, none occurred during half the years between 1871 and 1974. No tropical storm activity at all was reported from 1903 to 1908. Therefore, the average occurrence of hurricanes and tropical storms has little meaning when applied to any one year.

The Texas coast is long, and considering the size of any hurricane, it can be seen that one storm may not affect the entire coast. The storm tracks show that, in general, storms approach the coast at right angles (Appendix III). However, in some unusual cases storms may travel parallel to the coast, causing damage along almost the entire coast of Texas.

Climatological frequencies are usually accepted as probabilities for the future. In this case, with approximately a hundred years of records (1871-1974) available, some reliance can be placed upon the determined climatological frequencies and they may be interpreted as probabilities.

In Fig. 12, the coastline is divided into 50-mile segments and the probability of tropical storm and hurricane occurrence during any one year period is computed for each segment to show variability along the coast and to estimate frequency of damage. The computed segment percentages are smaller than those given for the entire Texas coast because of the much shorter coastline involved. Probability data for each coastal section is presented in terms of three classes of storms: (1) tropical cyclones, excluding tropical depressions; (2) all hurricanes; and (3) only extreme hurricanes. A 20 percent chance indicates one occurrence in five years. (Note: This type of data may vary because of the differing criteria established by various authors.)

If a tropical storm makes landfall in any one of the 50-mile segments, it is considered to affect the segment to the right. A hurricane is considered to affect all segments within 50 miles of the eye. An extreme hurricane influences the area 100 miles to the right and 50 miles to the left of the eye. Tropical storms which come within 50 miles of the coast without making landfall also are considered to affect coastal segments.

Fig. 13 shows the average number of years between tropical cyclones of different intensities for each coastal segment. At first look, there appears to be a discrepancy between Figs. 12 and 13. This occurs because more than one cyclone may hit during a season, and when this occurs it usually is counted in two or more segments. One cyclone during one summer and one the next summer would be counted as one year. An occurrence every other year would be two years.

More than one tropical cyclone can occur during any season within any 50-mile segments. Fig. 14, based on data from 1871 to 1974, shows the probability that two or more tropical storms or hurricanes will affect the same segment during the same year. A particular segment of coast will be hit twice during a season on the average of one year out of 20.

All the information shown here is presented as averages. The reader must be aware that hurricanes do not understand averages and each behaves as it wishes without regard to the actions of previous cyclones. Each has its own individual pattern. Nevertheless, the concept of using climatological averages as probabilities for the future is a standard procedure and, with a hundred years of data, these values may be considered a reliable guide.

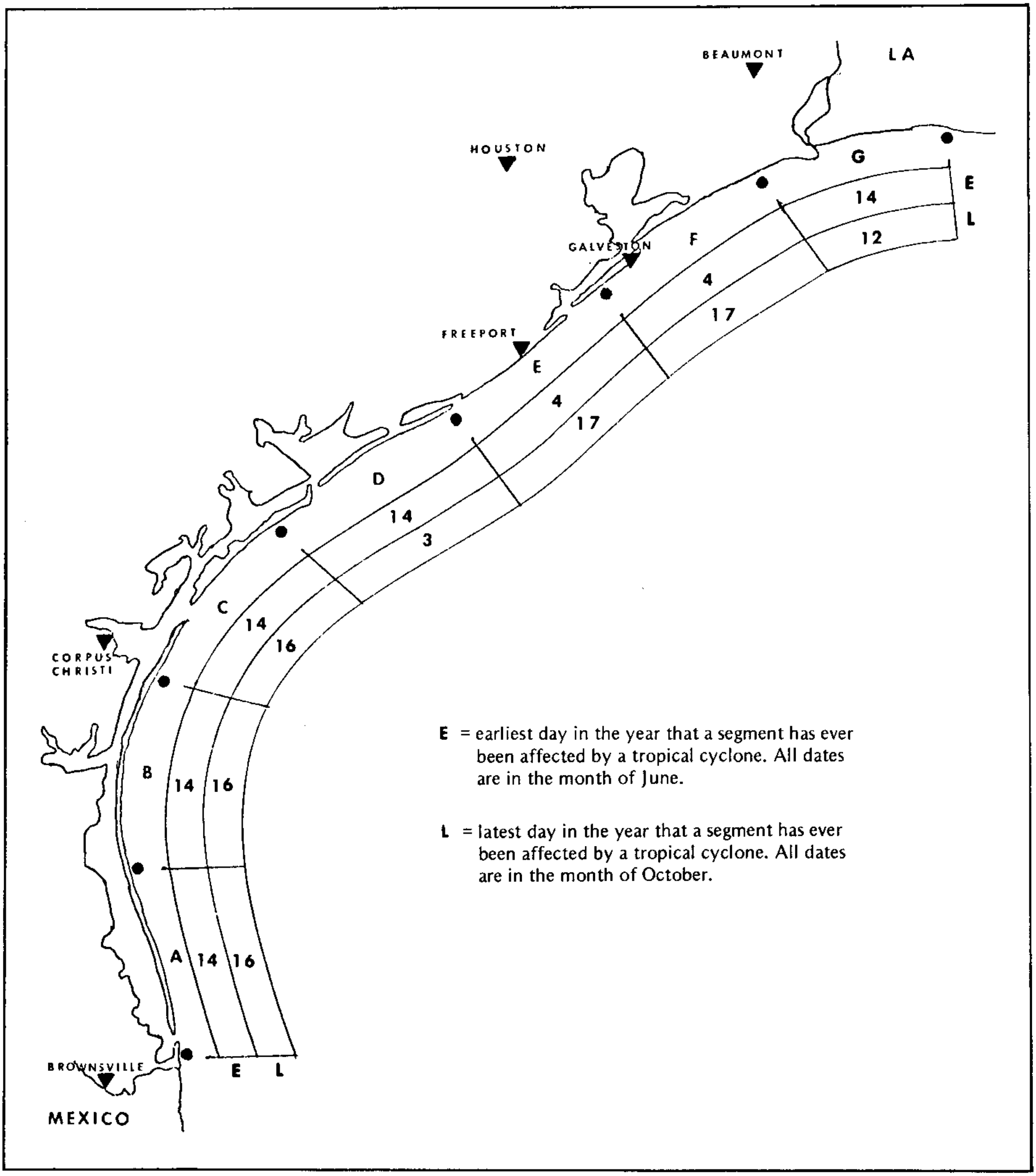


Fig. 11. The earliest and latest dates that a tropical cyclone has ever affected specified 50-mile segments of the Texas coast during the years 1971-1974.

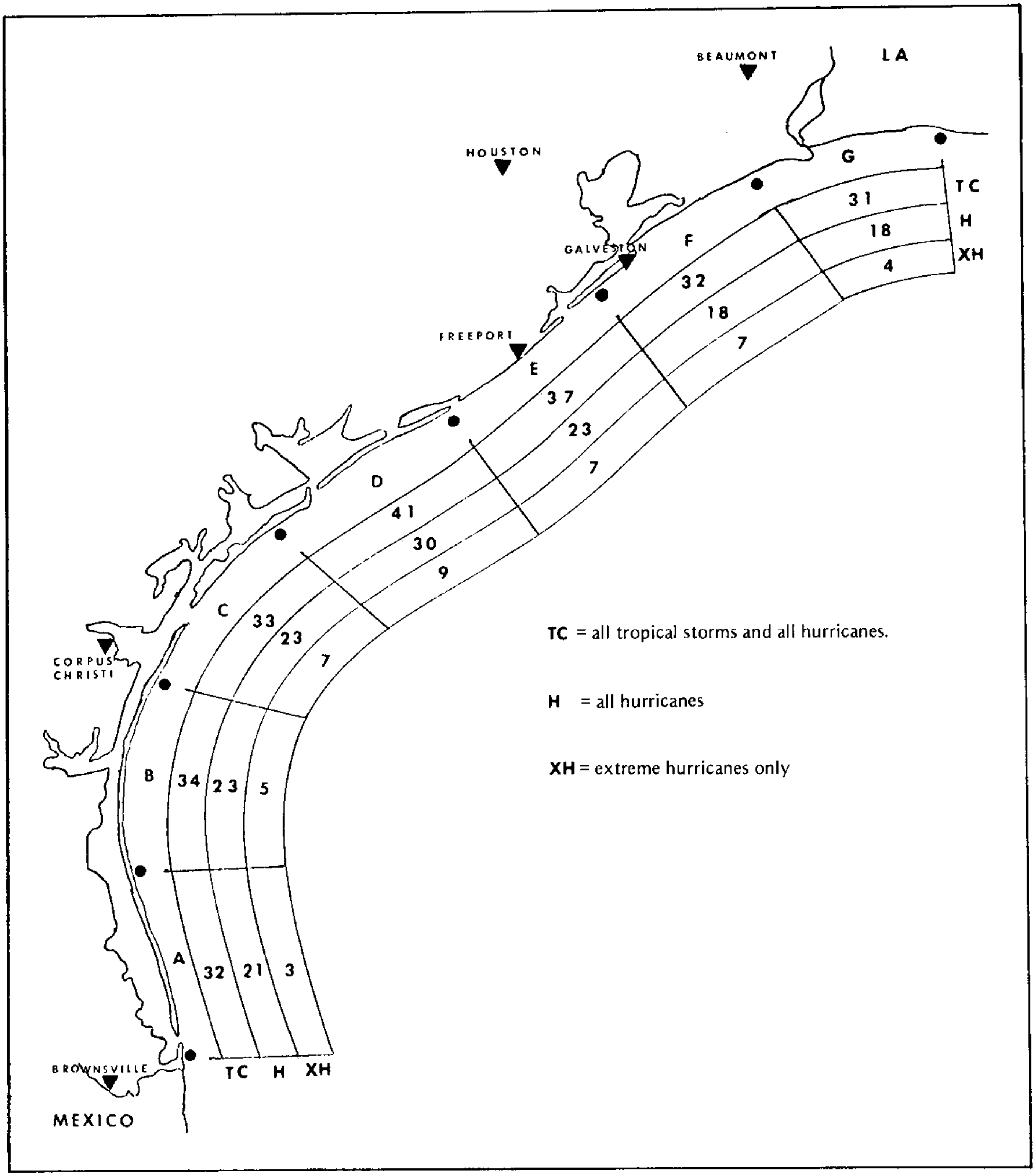


Fig. 12. Probability in percent of tropical storms and hurricanes affecting specified 50-mile segments of the Texas coast during any one year.

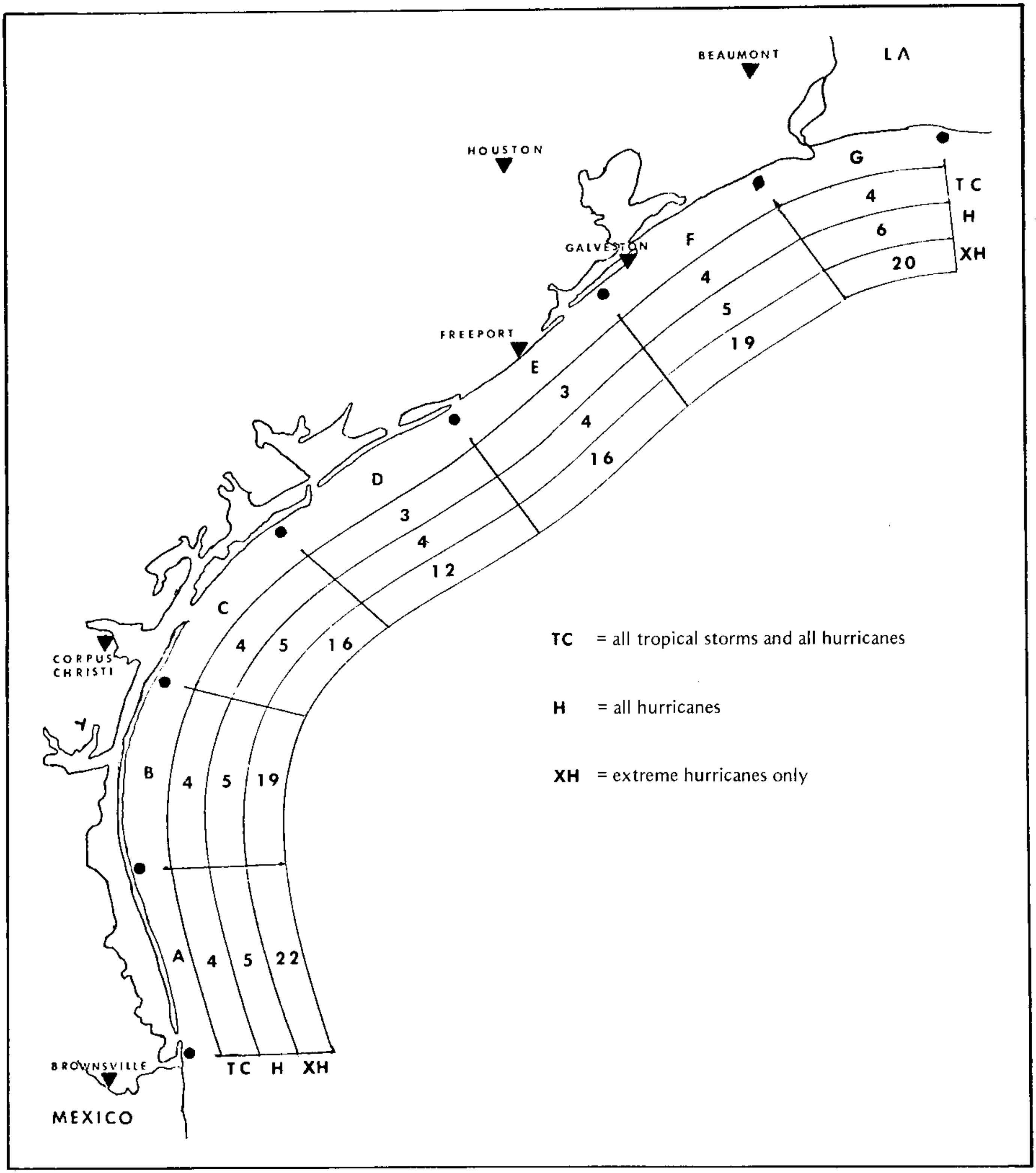


Fig. 13. Average number of years between the occurrence of tropical cyclones in specified 50-mile segments of the Texas coast based on data from 1871-1974.

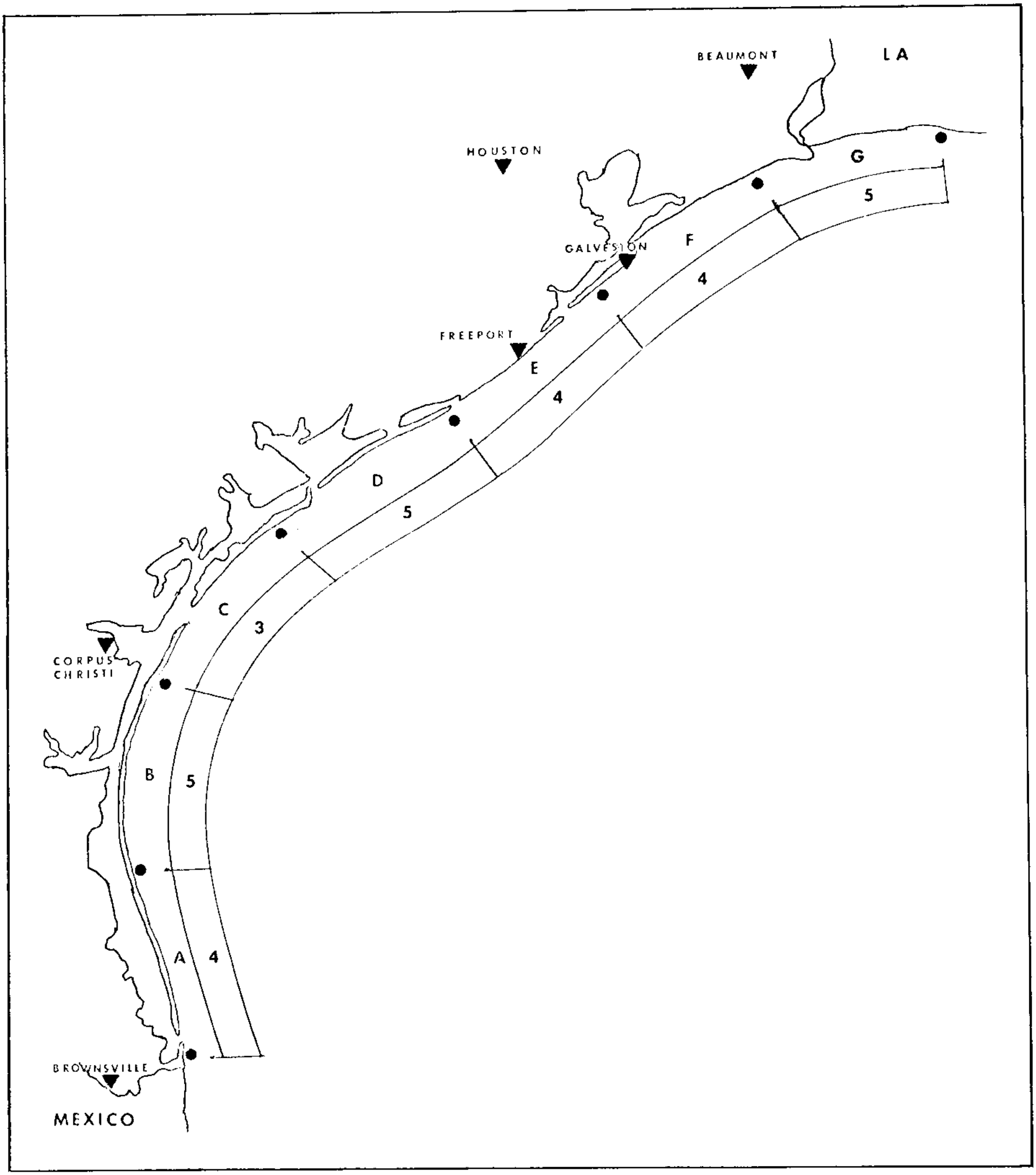


Fig. 14. The percent of years that two or more tropical cyclones have affected the same 50-mile segments during one season based on data from 1871-1974.

The Destruction

COSTS OF HURRICANES

In the United States, hurricanes have caused more damage than any other type of natural disaster. During the first 60 years of this century, 17,000 lives were lost and property damage amounted to $5 billion (Maunder 1970). The Galveston Hurricane in 1900 caused the most deaths (6,000 to 8,000), and, in Texas, Hurricane Celia (1970) was responsible for the greatest estimated damage of property ($500 million). Appendices IV and V detail costs of the most destructive Texas hurricanes.

Dollar damages soar with almost every hurricane due to increases in coastal populations and property values. Yet the death toll generally has decreased because of better warning systems. With radar and satellites to make remote observations, it is improbable that a hurricane could arrive unannounced at the Texas coast. The combination of radio and television alerts together with local warning networks should provide sufficient notice so that everyone can be prepared.

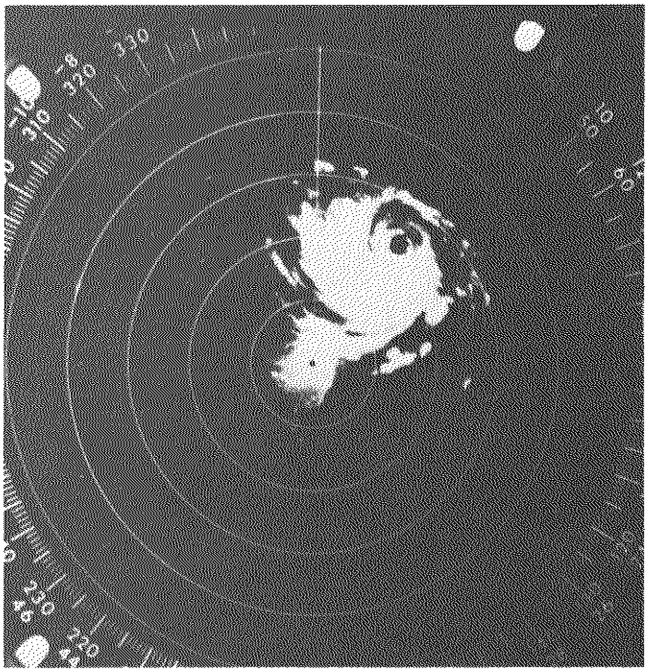


Fig. 15. This picture of Celia was taken from the Brownsville radar. The eye of the hurricane is the black hole to the northeast at the second ring from the center of the radar scope. The white area represents the heavy cloud and rain area. Photo courtesy of the National Hurricane Center.

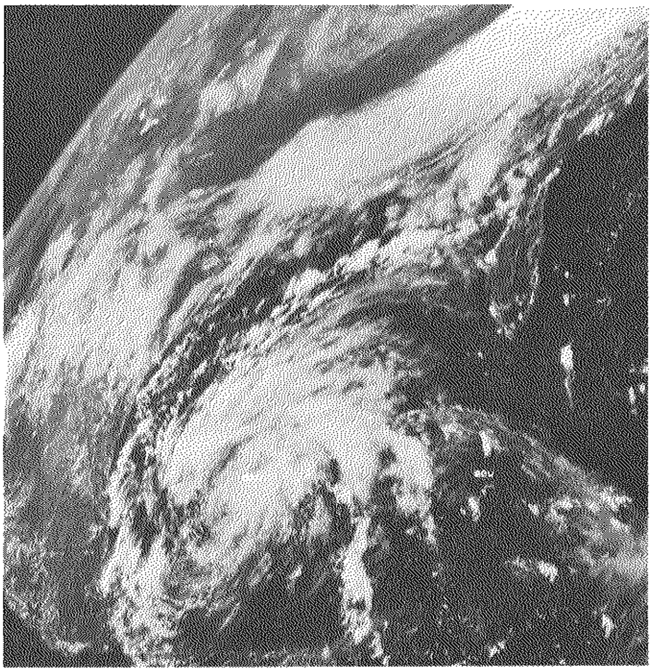


Fig. 16. A satellite picture of Hurricane Carmen (1974) just north of Honduras, where she caused extensive damage. The spiral cloud bands are easy to identify.

DAMAGE BY WINDS

Tropical cyclones are classified by their central pressure (see glossary in Appendix I) and by the speed of their winds. The tropical depression contains winds of less than 39 m.p.h. Tropical storms contain winds of 40-73 m.p.h. Hurricanes have sustained winds of 74 m.p.h. or more. When winds are between 100 and 135 m.p.h., the hurricane is designated as a major hurricane, and if the winds are greater than 135 m.p.h., as an extreme hurricane. The strongest gusts in a hurricane may exceed 200 m.p.h. but occur rarely.

In the recent history of hurricanes along the Texas coast, Celia (August 1970) is the outstanding example of damage caused by extremely high winds. As Celia moved inland just north of Corpus Christi, the peak gust at the airport was measured at 161 m.p.h. The anemometer (wind-measuring instrument) at Aransas Pass was blown away at 150 m.p.h.; later the wind was estimated at 180 m.p.h.

Hurricane Carla (September 1961) was another extreme hurricane. Carla had all the features (high winds, heavy rains, extensive storm surge, and tornadoes) that cause damage. Her strongest winds were estimated to be 170 m.p.h. at Port Lavaca.

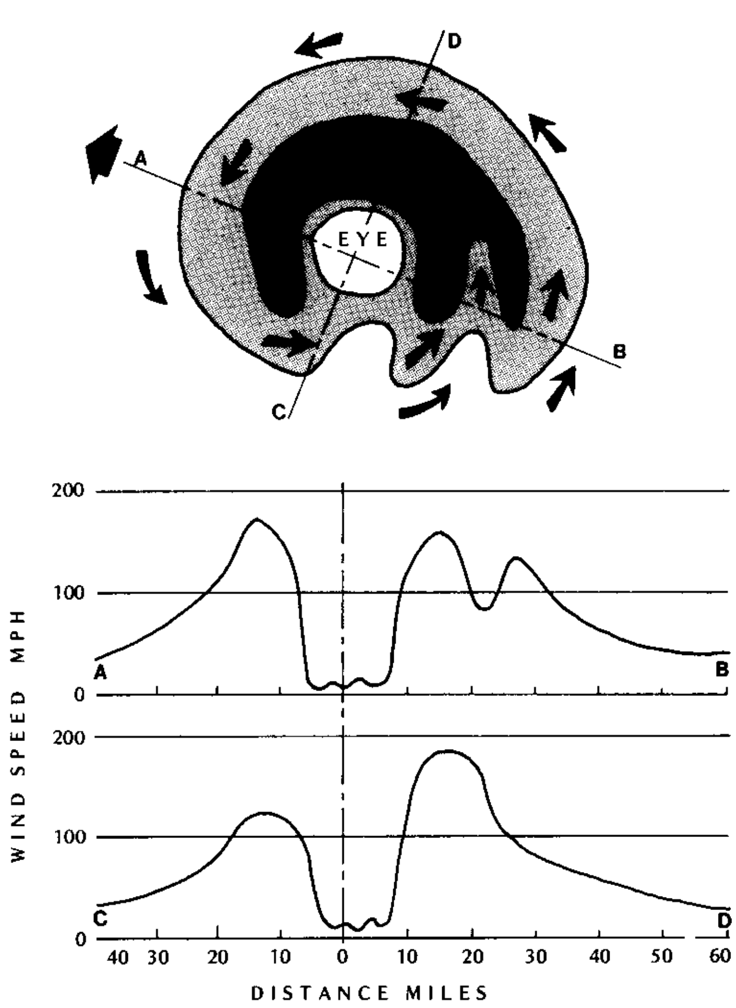


Fig. 17. A schematic representation of the wind distribution around the eye of an extreme hurricane like Carla or Celia. The large arrow pointing to the upper left indicates the direction of hurricane movement. The smaller arrows indicate the wind direction within the hurricane. The light hatching indicates the area of hurricane-strength winds. The darker hatching indicates the area of winds greater than 136 m.p.h. The graphs indicate the variation of wind strength along the lines A-B and C-D.

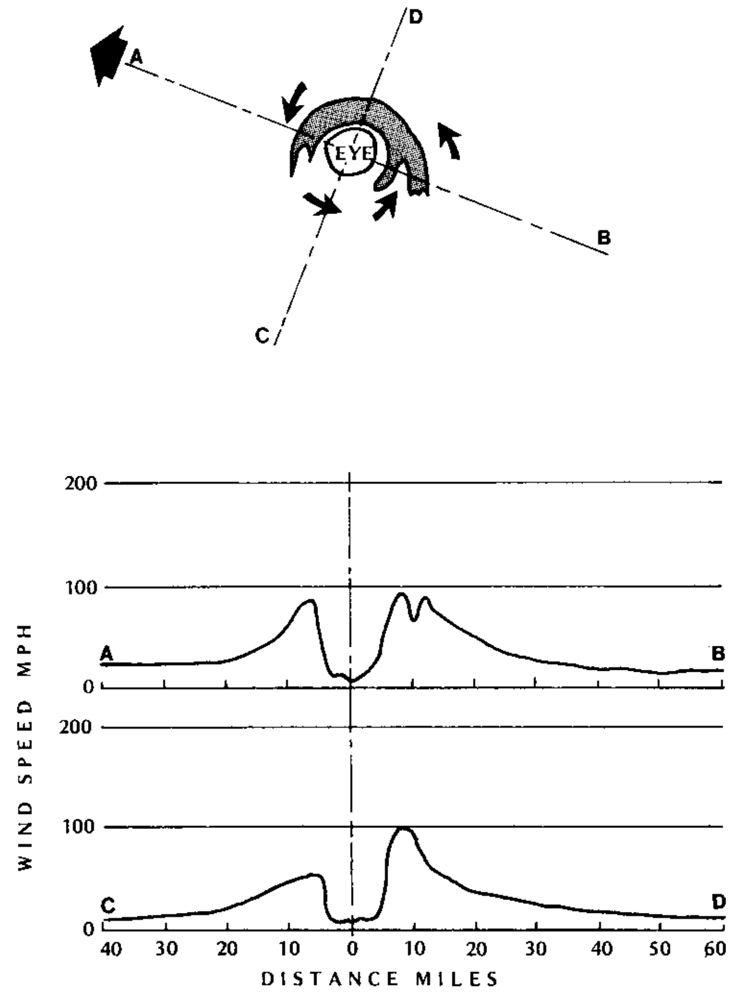


Fig. 18. A schematic representation of the wind distribution around the eye of a small hurricane. The large arrow pointing to the upper left indicates the direction of hurricane movement. The light hatching indicates the area of hurricane-strength winds. The smaller arrows indicate the wind direction within the hurricane. The graphs indicate the variation of wind strength along lines A-B and C-D.

The "eye" is the focal point of a hurricane. Fig. 15 is a picture of Celia taken from the radar scope at Brownsville. The eye is identified easily as the cloudless, circular area in the upper right (northeast) portion of the cloud mass. As in most cases, the eye is not centered in the cloud mass and the winds are not distributed uniformly around the eye. In the satellite picture of Hurricane Carmen (September 1974) shown in Fig. 16, the eye is barely visible. Hurricanes are eccentric, and each has different characteristics.

The general structure of hurricane winds is shown in Figs. 17 and 18. Fig. 17 illustrates the schematic wind distribution around an extreme hurricane like Carla (1961). Fig. 18 represents a smaller hurricane with hurricane-strength winds in only one sector of the cyclone. This hurricane is more representative of those found on the Texas coast than is the extreme hurricane of Fig. 17. Both are represented on the same scale so that comparisons can be made.

At wind speeds between 35 and 40 m.p.h., twigs are broken from trees and walking against or with the wind is difficult. With speeds in the 40's, slight structural damage occurs; shingles can be blown off roofs, and unsecured trash cans are scattered. When wind speeds reach 49 to 56 m.p.h., tree branches can break and significant damage can occur to structures.

The wind force applied to any object increases with the square of the wind speed (Fig. 19). Consider a house 100 feet long and 10 feet high with a 100 m.p.h. wind blowing against it. Since wind at 100 m.p.h. exerts a force of about 40 pounds per square foot, the total force exerted against one side of the house would be 40 x 100 x 10 or 40,000 pounds! With a wind of 160 m.p.h., this force would be 100 x 100 x 10 or 100,000 pounds! When rain is driven by the wind, the force exerted on the side of a building is even greater. Few buildings are designed to withstand such force without damage. Fig. 20 illustrates damage by high winds to buildings.

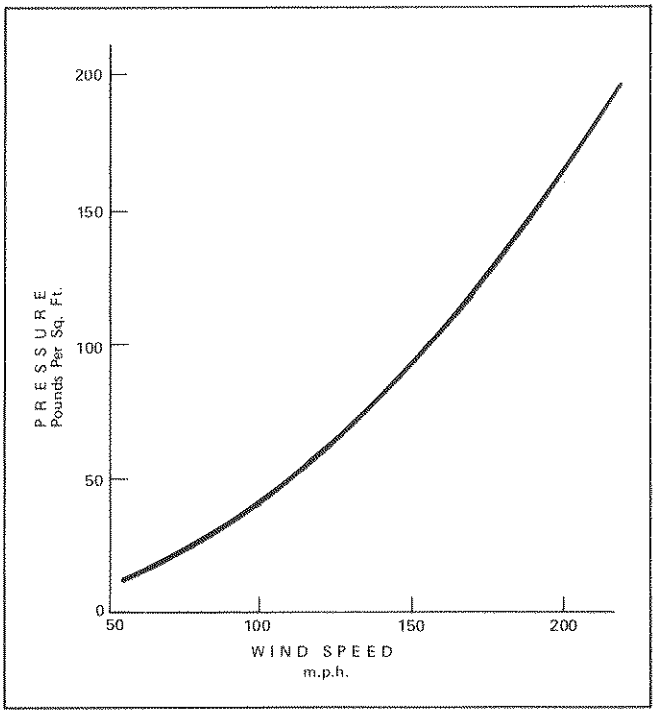


Fig. 19. The wind pressure exerted on a surface perpendicular to the wind flow varies with the wind speed, as shown.

Fig. 20. After the masonry wall in Corpus Christi yielded to the winds of Hurricane Celia (1970), the roof fell. Photo courtesy of the Texas Highway Department.

Trees also are blown over or uprooted by hurricane-force winds (Fig. 21), and whole forests may be leveled. After Hurricane Camille (1969, Mississippi), trees to the west of the eye (where winds were from the north) were lying parallel to each other with their crowns pointed south. To the east of the eye (where winds were from the south), the trees were lying parallel with crowns pointed north.

Overhead power and telephone lines frequently are broken by strong winds. These downed electric lines are a hazard if the power is on. Furthermore, blowing debris from destroyed buildings can cause extensive damage to other structures and serious injuries to people not in shelter.

DEVASTATION BY STORM SURGE

Storm surge, an abnormal rise in the level of the sea, causes the greatest concentration of death and destruction in a hurricane. The continual pounding of the storm surge (which may reach heights up to 20 feet) with waves superimposed can destroy almost any manmade structure. Fig. 22 shows the storm surge during Hurricane Carla.

Many people who stayed in their homes near the coast during the Great Galveston Hurricane of 1900, and during the Indianola hurricanes of 1875 and 1886, were buried in the resulting rubble. Some persons who left during the height of the storm, because their homes were being destroyed, were washed away and never found. When Hurricane Camille hit the Mississippi coast near Pass Christian in 1969, her storm surge destroyed numerous structures, including a three-story, 40-unit apartment building. Only the foundation of the apartment building remained. About a dozen tenants held a hurricane party during the storm--their bodies were never found.

In some areas of the world, the storm surge can reach heights of 40 feet or more. A few years ago an extreme hurricane (called cyclones in the Indian Ocean) hit the islands off the coast of Pakistan (now Bangladesh). The storm surge killed an estimated one million people and destroyed almost all the crops and housing on the low, flat islands.

Another hazard of the storm surge was demonstrated by Hurricane Audrey, which hit the west Louisiana coast near Cameron in June 1957. Even though a hurricane watch had been issued two days in advance and hurricane warnings were issued 14 hours before high winds and high tides reached the coast, few people evacuated the area. Many people who stayed were drowned. It is thought that the majority of people who drowned sought safety by climbing into high trees and then fell into the rising flood waters after they were bitten by snakes also taking refuge in the trees.

The storm surge is highest where onshore winds are strongest -- in the right front quadrant of the hurricane. Fig. 23 (Harris 1963) shows the distribution of storm surge height above mean sea level at varying distances from the eye of Hurricane Audrey (1957). Audrey was moving northward so the highest storm surge occurred to the right (east) of the eye. Note that a storm surge greater than eight feet high can extend 150 miles along the coastline. Surf conditions and riptides also are dangerous for hundreds of miles along the coast.

The height of the storm surge depends on a variety of factors. In addition to hurricane size and intensity, the

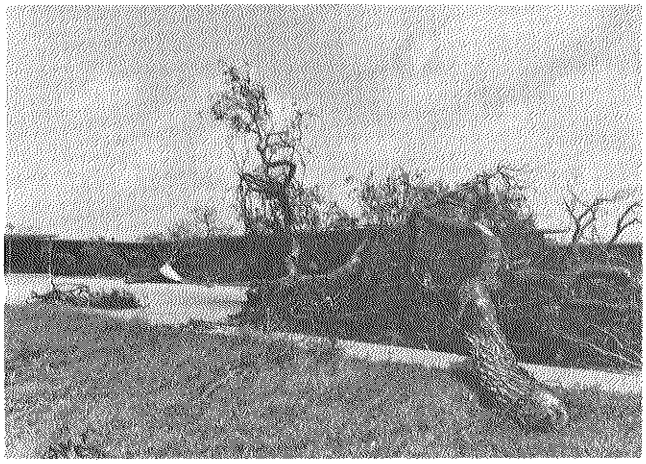


Fig. 21. Thousands of trees were snapped by the winds of Hurricane Celia. Photo courtesy of the Texas Highway Department.

angle at which the storm strikes the coast is one factor. Storms that move onshore at right angles to the coast will cause a higher storm surge than those that hit obliquely. The height of regularly occurring tides can add to or subtract from the storm surge. The slope and profile of the shoreline and ocean bottom near the beach are important because they can create a bottleneck effect, causing much higher storm tides. Barrier islands, inlets, and estuaries also affect size of the storm surge, as do the amount of vegetation and construction in the impact area. Because many complex factors are involved, height forecasts for the storm surge in a given area are not always accurate.

Flood waters of the storm surge usually come in like a high tide but rise much faster. Sometimes in bays the storm surge starts a series of fast-moving waves that oscillate from one side of the bay to the other. The condition is illustrated by trying to carry water in a flat pan; the rush of water from one end of the pan to the other represents the oscillation in bays. This water movement is called a "seiche" (pronounced

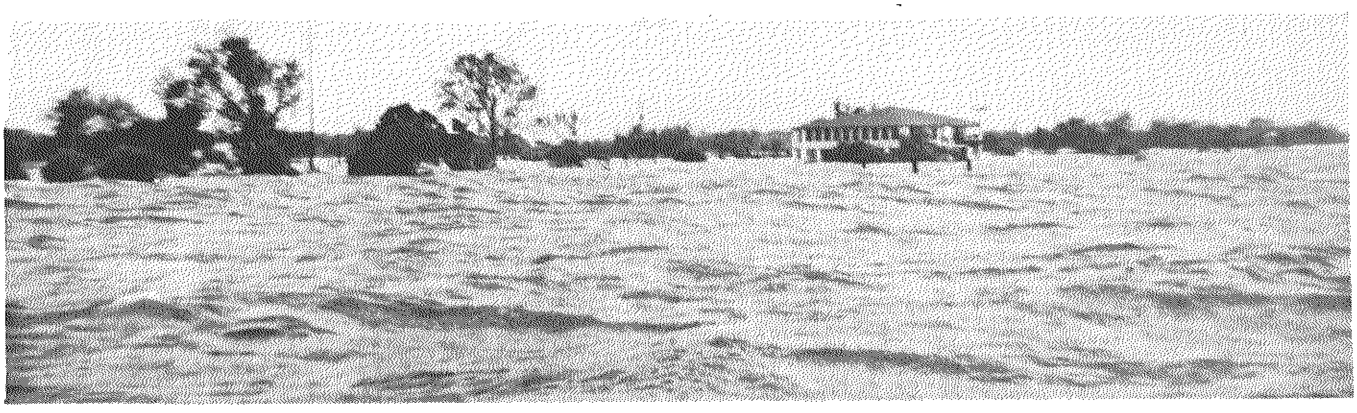


Fig. 22. This view shows land inundated by the storm surge during Hurricane Carla (1961). The winds have diminished, but the floods remain. Photo courtesy of the Texas Parks and Wildlife Department.

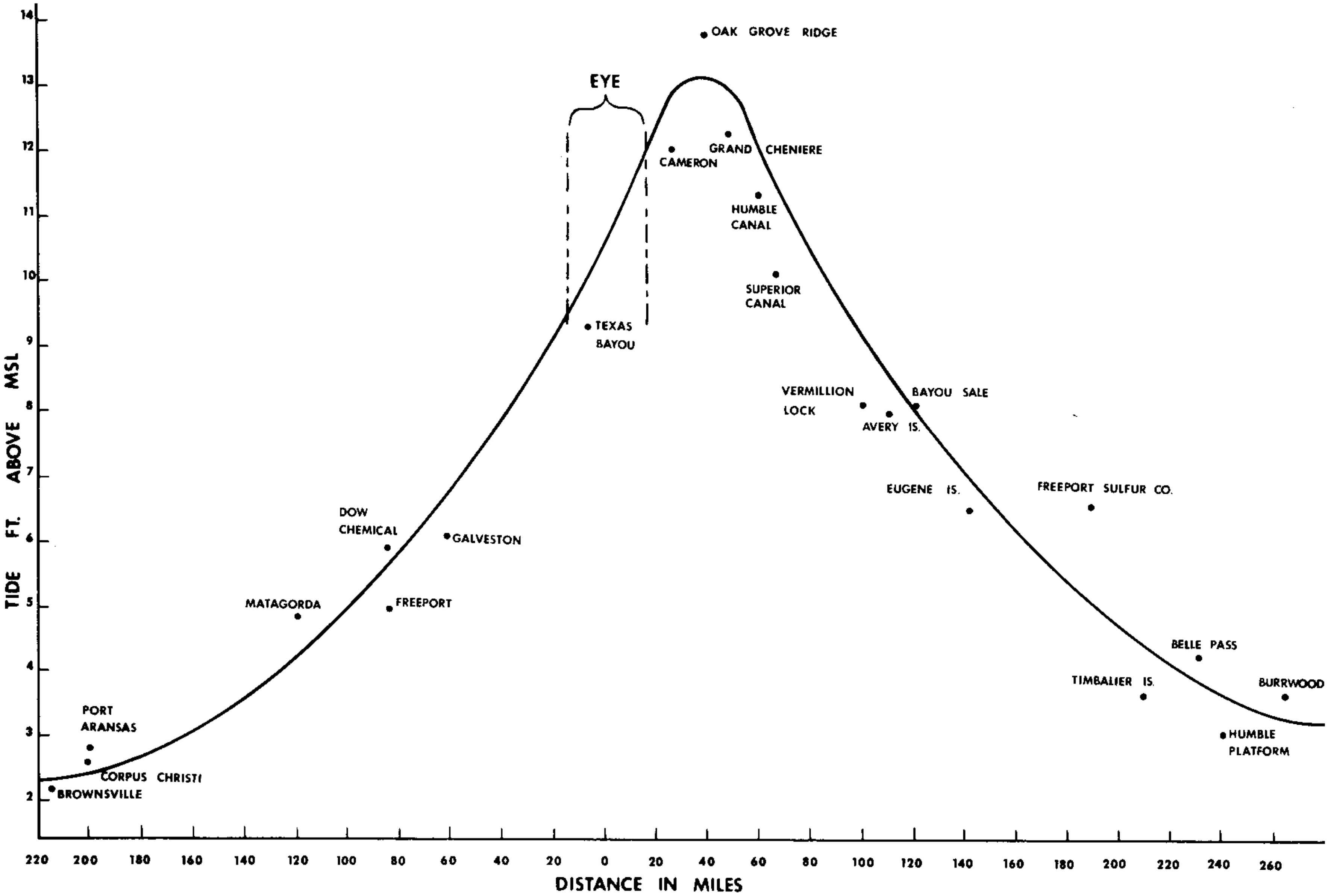


Fig. 23. This chart shows the distribution of maximum tide heights above mean sea level (MSL) recorded during Hurricane Audrey of 1957 (Harris 1963).

Fig. 24. This is one of three large boats that were washed almost half a mile inland from Lavaca Bay onto Texas State Highway 316 between Indianola and Port Lavaca during Hurricane Carla. Photo courtesy of the Texas Highway Department.

"sayche"). Survivors have described the sudden inflow as "great walls of water which swept all before them." Forecasts of this condition are beyond present capability.

Tannehill (1956) gives an account of a seiche at Coringa on the Bay of Bengal that illustrates the destructiveness of the storm surge, during which the town and 20,000 inhabitants disappeared:

> Coringa was destroyed in a single day. A frightful phenomenon reduced it to its present state. In the month of December 1789, at the moment when a high tide was at its highest point, and that the northwest wind blowing with fury, accumulated the waters at the head of the bay, the unfortunate inhabitants of Coringa saw with terror three monstrous waves coming in from the sea, and following each other at short distances. The first, sweeping everything in its passage, brought several feet of water into the town. The second augmented these ravages by inundating all of the low country, and the third overwhelmed everything.

Damage by the storm surge occurs along the coastline for hundreds of miles from the center of the hurricane. Far from the eye, the storm surge is evidenced by numerous Portuguese men-of-war or increased seaweed and other debris washed up on beaches. Closer to the center there is vast erosion of some beaches and considerable deposition of debris on others. Marine and shore equipment, as well as boats, often are torn from their moorings and washed hundreds of yards inland (Fig. 24). Fig. 25 shows houses lifted from their foundations and floated onto the road. Often during the evacuation before a hurricane, livestock must be left to become victims of the storm surge (Fig. 26). After the hurricane passes, authorities must dispose of the carcasses before they become health hazards.

Along the Texas coast areas of land subsidence are more vulnerable to destruction by the storm surge. During the last 30 years, some places have sunk as much as seven feet, and subsidence is expected to continue at about the same rate. If the storm surge from Carla (1961) was two feet where the land has since subsided two feet, a similar storm today could cause the storm surge to be four feet deep. Areas that survived previous storm surges may not be safe today. Locations lower than 20 feet above mean sea level must be considered prime areas to be flooded by the storm surge, and areas higher than 20 feet above mean sea level are not always secure from flooding.

According to some specialists, the effects of the storm surge are not always detrimental. Bays are flushed of pollutants, and sand is transported from the continental shelf onto beaches to replenish previously lost sand. Sometimes this shifting of sand exposes old shipwrecks and artifacts.

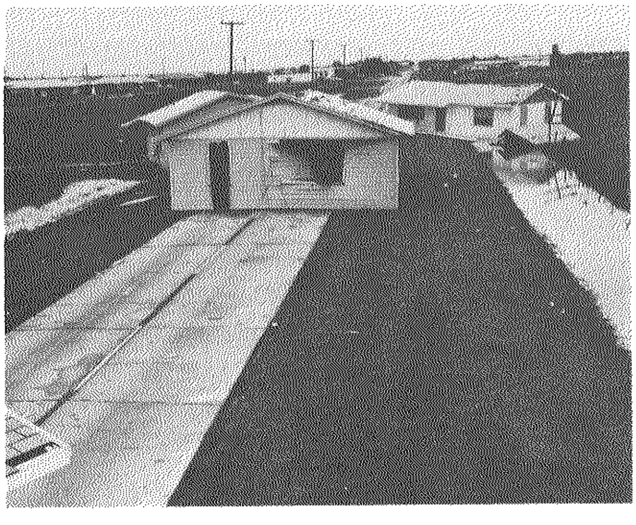


Fig. 25. Houses struck by the storm surge were floated and blown onto Texas State Highway 35 near Palacios city limits during Hurricane Carla. Photo courtesy of the Texas Highway Department.

DISASTER FROM RAINFALL AND FLOODING

Rainfall from tropical cyclones is *extremely* variable, and depends on the diameter of the rainy area and the speed of cyclone movement. Total rainfall is greatest for large hurricanes that move slowly. But even a tropical depression that is not named can drench a vast area.

The world record for 24-hour rainfall (73.62 inches) was associated with a typhoon in the Philippine Islands. Although hurricanes of the Texas coast have not produced such spectacular rainfall, heavy rains have occurred.

Heavy rainfall can cause flash floods and river system floods, both of which can produce extreme damage. The flash flood, which lasts 30 minutes to four hours, is caused by heavy rainfall over a small area where drainage cannot carry away excess water without overflow. For example, a dry stream bed can fill with water and overflow low bridges, underpasses, or low-lying areas. Danger to local residents occurs in areas usually not subject to high water. The strong current can carry cars off the road, erode roadbeds, and wash out bridges.

The river system flood (Fig. 27) develops more slowly. Larger rivers may overflow their banks as they gather runoff, including that from flash floods. This type of flood, which may not start until two or three days after the hurricane, may persist for a week or more. Although the current in the river channel is strong, most of the floodwater is overflow with comparatively weak current. While the flash flood may be the killer, the river flood covers such an extensive area that destruction of property and crops is greater. After the water retreats, buildings are full of mud, furniture is warped, and rugs are unusable.

Wind-driven rain also causes damage. Rain can enter buildings around windows, through cracks, and under shingles, causing damage to interiors. Fig. 28 shows the driving rains of Hurricane Carla.

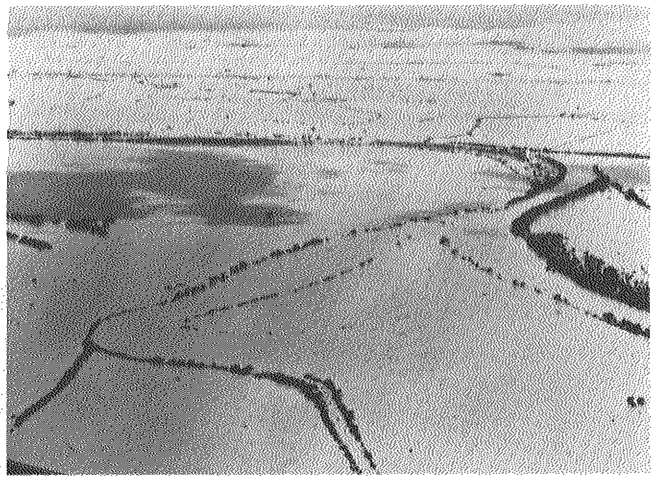


Fig. 27. These flood waters from Hurricane Beulah are near Los Ebanos. The double row of trees in the foreground mark the beds of two creeks. Photo courtesy of the Texas Highway Department.

Hurricane Beulah (1967) caused the most extensive flooding from rainfall of any reported tropical cyclone in Texas. Beulah struck the coast just north of Brownsville, moved northward to a location close to Alice, Texas, turned toward the southwest and moved slowly into Mexico, where she dissipated.

The total rainfall from Beulah exceeded 30 inches at some places (Falfurrias reported 36 inches). The greatest 24-hour rainfall, an estimated 15 inches, was at Sebastian. Although not close to world records, these amounts did cause severe flooding of river systems throughout south Texas and northcentral Mexico.

Fig. 26. Livestock were left in the wake of Hurricane Carla's storm surge on Texas State Highway 35 near Karankawa Bay. This sight was common along the Texas coast in September 1961. Photo courtesy of the Texas Highway Department.

DEADLY TORNADOES

Two significant features of the hurricane-spawned tornado are its reduced size (about half the size of its Great Plains cousin) and its short duration (usually minutes). Consequently, the area affected is small, usually 200 to 300 yards wide and less than a mile long. Nevertheless, this area often is ravaged completely.

Generally tornadoes occur to the right of the direction of hurricane movement. The area within angles of 10 to 120 degrees from the direction of movement includes 94 percent of the tornadoes, most of which occur between 60 and 240 miles from the eye and outside the area of hurricane-force winds. Tornadoes occur more frequently when a hurricane moves northward, less frequently when it moves westward. Hurricane Beulah (1967) was a notable exception.

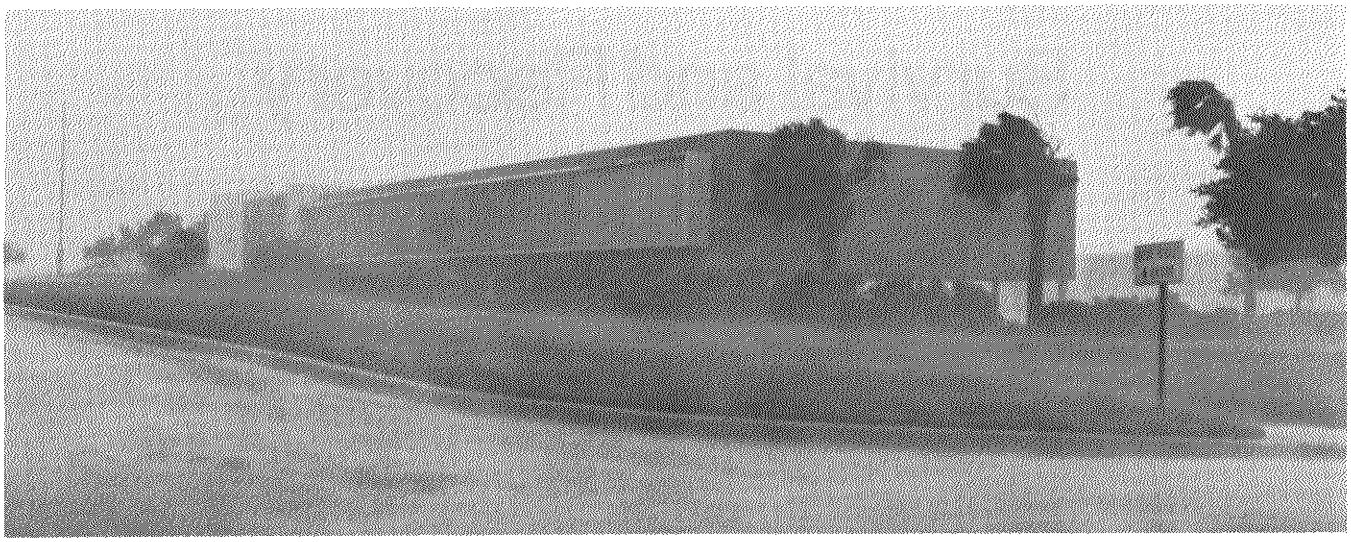


Fig. 28. The wind and rain of Hurricane Celia is shown near the District Highway Office at Corpus Christi. No pictures were taken outside during the height of the storm because of the danger. Photo courtesy of the Texas Highway Department.

In recent years, reporting systems have improved so that some general knowledge exists of the number and geographical extent of hurricane-generated tornadoes. In the United States, Beulah holds the record for hurricane-associated tornadoes with more than 100; Carla (1961) is second with 26. Because Beulah's tornadoes hit sparsely populated areas, the death toll and property damage were small. If these small but deadly tornadoes hit larger cities during future hurricanes, casualty lists and property damage can increase.

DELAYED DANGERS

When a hurricane strikes, the immediate danger is caused by flooding and strong winds. But secondary or residual dangers continue after the major damage has occurred.

Utility systems may not be operating. There is danger of shock from electric power lines that have been blown down. Power for any use, from light to refrigeration, may not be available. If telephone and telegraph lines also have been blown down, direct communication can be limited to battery-powered radios.

Transportation systems can be inoperative. Bridges and roads can be washed out or flooded. Debris can block roads. Movement of food, medical supplies, and necessary equipment can be impeded. Water systems can be flooded and polluted. Sewage and waste cannot be disposed of as usual.

Drowned animals, lack of drinking water, failure of sewage systems, and living in shelter conditions are conducive to outbreak of disease. Numerous problems, including the threat of epidemics, confront public health services.

Snakes driven from their natural habitats by the high water (Fig. 29) also can cause a minor problem. During almost every hurricane people are bitten by snakes and have difficulty getting medical attention because of transportation and communication breakdowns. Snakes, which are strong swimmers, will be along roads, in the remains of buildings, in trees, and in other high and dry places.

Finally, there is man. During every disaster there are people who take advantage of the confusion and misery to loot and pilfer.

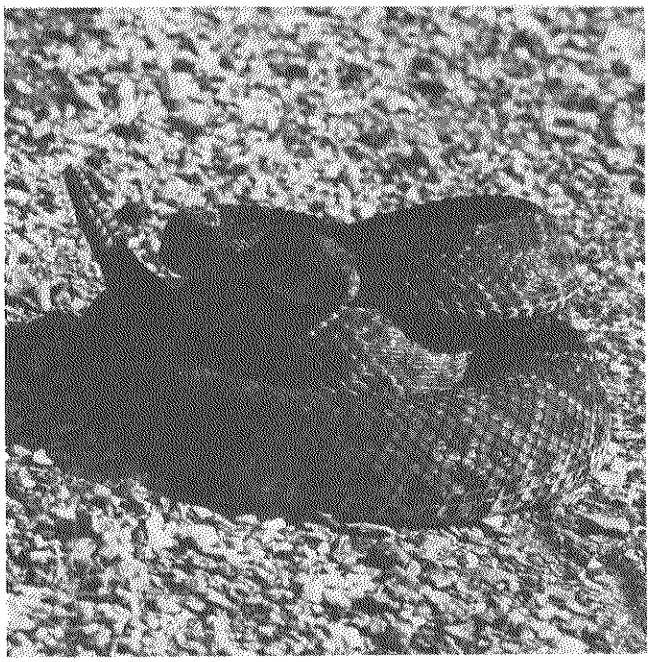


Fig. 29. This large rattlesnake moved to the shoulder of the highway to escape the flood waters of Hurricane Carla. Photo courtesy of the Texas Highway Department.

Survival and Recovery

GETTING READY

This chapter, probably the most useful section of the booklet, provides information to aid coastal residents in saving lives and describes what federal, state, and local agencies do before, during, and after a hurricane. Since the key element in survival and recovery is *preparation*, each individual should plan to protect himself and his family and minimize property damage. Actions that individuals should take when a hurricane threatens are listed. Perhaps most important are the personal checklists in Appendix VI, which individuals are urged to review after reading this chapter. Extra copies of the checklists, to share with friends, have been included at the back of this booklet. Hurricane hazards have been described in the previous chapter, and now is the time for *you* to decide how to cope with these dangers before they arrive. The only way to prepare effectively for a hurricane is to consider all types of potential damage!

WHAT TYPE OF DAMAGE?

One significant question to be answered is, "What type of destruction will a particular hurricane bring when it strikes the coast?" Will the damage occur through storm surge, high winds, tornadoes, heavy rainfall, or a combination of these?

The storm surge, an abnormal rise in sea level accompanying a hurricane, is a hurricane's greatest killer. Averaged over the years, about nine of 10 people who died during hurricanes drowned due to the storm surge. Hurricane Carla's storm surge reached a maximum height of 21 feet and extended inland more than 10 miles in some areas. Houses were floated off their foundations and were destroyed by continued wave action superimposed upon the waters of the storm surge. High winds, continual waves, and floating debris made swimming to safety almost impossible for people fleeing from their flooded homes. To obtain maps that show the areas covered by previous storm surges, see Appendix VII, Part 3.

The high winds of a hurricane or tropical storm are often strong enough to damage almost any structure. Short wind gusts (less than one minute in duration), which can exceed sustained wind velocities by 50 percent, develop a swinging action in signs, trees, and other bendable structures. Gusty winds cause extensive damage because of this rocking effect, alternately pushing a structure to its limit and allowing it to swing back before the cycle is repeated. Trees and signs are often uprooted or snapped.

Window glass is blown in on the windward side of buildings and out on the downwind side. A device has been developed that is said to protect windows (see Appendix VII, Part 1). Homeowners should board their windows to prevent damage by wind or flying debris. At hurricane speeds air-borne debris become lethal projectiles--imagine a 4 x 8-foot of tin roofing sailing through the air at these speeds!

Hurricanes often spawn tornadoes that can cause extensive damage. Smaller than its Great Plains cousin, the hurricane-spawned tornado usually affects an area less than 300 yards wide and a mile long; nevertheless, it is just as deadly.

Flooding, caused by heavy rains, usually extends farther inland than other types of damage. For example, Hurricane Agnes (1973) made landfall along the Florida coast but caused extensive flooding in Pennsylvania and New Jersey. Rainfall accounted for almost three-fourths of Hurricane Beulah's flooding (1967), and storm surge accounted for the remainder.

Again, the only way to prepare effectively for a hurricane is to consider all types of potential damage.

HELP FROM NATIONAL AGENCIES

Great strides have been made in forecasting the paths of tropical storms and hurricanes. In fact, the 12-hour forecast error on landfall averages less than 40 nautical miles. Nevertheless, much remains to be learned from continuing research.

When a tropical disturbance is detected (usually by satellite), the National Hurricane Center (NHC) in Miami, Florida, swings into action. The disturbance is monitored continually, and bulletins are issued to the Hurricane Warning Service Network and the news media. Aircraft may fly into the cyclone to gather data and to evaluate the possibility of intensification. If the disturbance matures into a tropical storm, a feminine name is assigned. Appendix IV lists names for tropical storms and hurricanes from 1975 through 1984.

When the disturbance becomes a tropical storm, the NHC calls the hurricane warning system to full alert and issues public advisories. Advisories are numbered consecutively and are issued every six hours at 5 a.m., 11 a.m., 5 p.m., and 11 p.m Central Daylight Time (CDT). They include information on location, direction, speed of movement, intensity, radius of storm, radius of gale force winds, and central pressure.

When a hurricane is expected to strike the Texas coast, the point of landfall and maximum wind speeds are forecast. Sometimes unexpected changes take place in the hurricane's structure or movement within a short period of time. Hurricane Celia's explosive intensification just prior to landfall and Hurricane Beulah's recurvature to the southwest after hitting the coast are examples.

When a tropical storm or hurricane approaches land, the Hurricane Warning Office (HWO) in that area issues local warnings. Generally, the HWO prepares advisories if the storm is moving through its area or may progress there within 12 hours. The advisories are issued simultaneously by the National Hurricane Center. Additionally, for the 1975 hurricane season the NHC will initiate the Hurricane Disaster-Potential Scale as an estimate of expected damage. Specifics of the scale are given in Appendix X.

Meteorologists at the NHC and Hurricane Warning Offices (New Orleans, Washington, D.C., San Francisco, and Honolulu) forecast the movement, development, and storm surge heights of all tropical cyclones that may strike the United States. They also analyze tropical cyclones of the previous season to develop more accurate forecasting methods. In recent years the forecast accuracy for paths of tropical cyclones has increased more than 10 percent; the average 24-hour displacement error is now less than 100 nautical miles.

Fig. 30. A National Guardsman stands watch at a roadblock in Corpus Christi as Hurricane Carla approaches, September 1961. Photo courtesy of the Texas Highway Department.

The National Weather Service Hurricane Warning Office in New Orleans issues hurricane warnings for the Texas coast. Advisories and bulletins (see Appendix I for definitions) issued by that office include:

- Hurricane watch or warning.
- Estimate of storm tide and flood danger in coastal areas.
- Cautionary advice to small craft.
- Gale warnings along the periphery of the cyclone.
- Tornado forecast information.

Bulletins containing additional information about the tropical cyclone are issued at two-hour intervals, or more often if necessary, as long as the disturbance retains its identity or threatens life and property.

Local Weather Service Offices issue Local Action Statements at two- or three-hour intervals, or more frequently if conditions warrant, when tropical cyclones threaten the Texas coast. These statements, which amplify releases from the Hurricane Warning Office, specify:

- Coastal and bay areas or counties where warnings apply.
- Detailed recommendations for evacuation and suggested completion times.
- Places and times of storm surge, including times when critical roads or escape routes are expected to be flooded.
- Other emergency actions and the times for completion.
- Tide readings, wind conditions, rainfall measurements, and areas of possible flooding from excessive rainfall.

Weather Service Offices in the coastal region of Texas are located at Port Arthur, Galveston, Houston, Victoria, Corpus Christi, and Brownsville. These offices have direct communications with disaster preparedness officials and the media via telephone, teletype, and radio.

The U.S. Army Corps of Engineers also plays an important role in minimizing hurricane damage. The Corps has made extensive surveys of damage caused by past hurricanes. These surveys provide background information needed for construction of sea walls to reduce storm surge damage, and levees and improved drainage to minimize flooding by rivers. Some of these protective structures have been completed along the Texas coast.

The American Red Cross and the Salvation Army are two of the many agencies involved in natural disaster recovery operation. In cooperation with state and local officials, the Red Cross plans in advance to operate relief centers and shelters and to supply vital services, food, and clothing. The Salvation Army assists in solving individual and family problems.

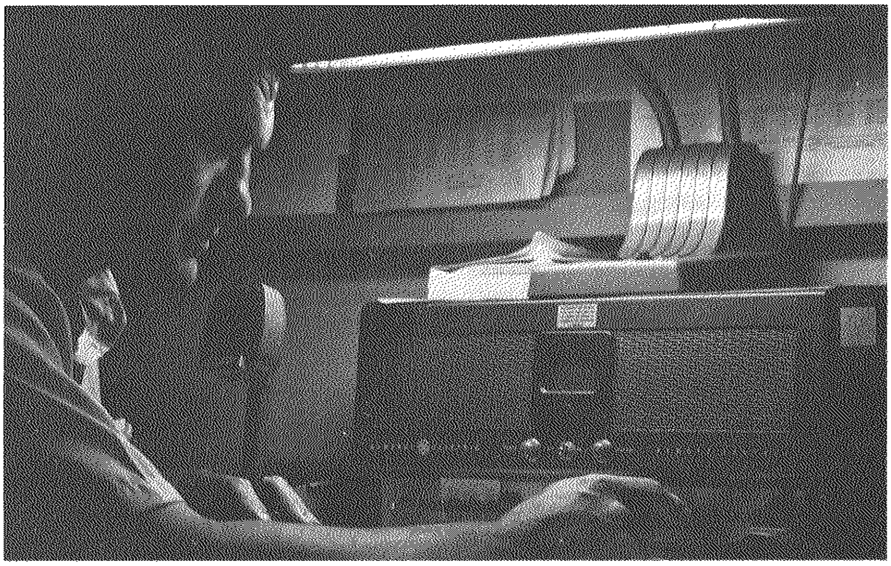


Fig. 31. A Texas Highway Department employee maintains radio communications by using an auxiliary generator in Corpus Christi during Hurricane Celia, August 1970. Photo courtesy of the Texas Highway Department.

PLANS OF STATE AND LOCAL ORGANIZATIONS

At all levels of government, preparations for recovery from man-made and natural disasters are reflected in laws and emergency operating plans. The Texas Disaster Act of 1973, S. B. No. 786, provides state and local governments with the general authority for coordinating and implementing emergency actions when a hurricane threatens.

The state Emergency Operations Center (EOC) is located in the Department of Public Safety Building in Austin. The state Director of Defense and Disaster Relief activates the Center whenever an actual or threatened disaster, such as a tropical cyclone, is reported. The EOC offers advice and dispatches needed materials to affected areas.

Most EOC assistance is in the form of manpower, i.e., members of the Department of Public Safety, the National Guard, and the State Highway Department. Heavy equipment also may be sent by the Center.

Cities and counties have local Emergency Operating Centers. Executive Order DB-8, dated October 1, 1973, states in part:

> The Mayor of each incorporated town in this State will be recognized as the Municipal Disaster Coordinator/Director for his jurisdiction.
>
> The County Judge of each county will be recognized as the County Disaster Coordinator/Director for the area of the county outside the corporate limits of the municipalities in the county.

The intent of Executive Order DB-8 is elaborated further on page 4 of *Disaster Planning--A Manual For Local Governments.*

> In either case, these officials may appoint or select by court order or city ordinance a coordinator of disaster services to administer the local program. Such coordinator will be responsible to the county judge or mayor, as the case may be.
>
> If a city and county concur in such an arrangement, it is authorized under the Disaster Act of 1973 to have a joint disaster program and organization with one coordinator appointed and authorized by both the city and the county. Some of the outstanding disaster programs in the State are joint city-county efforts.
>
> It is desirable for the county judge or his appointed disaster coordinator to appoint a disaster coordinator for each unincorporated town or community in the county. Many of the unincorporated towns in Texas have volunteer fire departments as one of the few organized community efforts for providing a community service and the local leadership might be found in such an organization.

The local EOC of a coastal community should have plans to deal with hurricane problems. These plans should include:

- Communication systems--local, state, and national.
- Methods of warning citizens.
- Dissemination of evacuation and shelter information.
- Operation of shelters in cooperation with the American Red Cross.
- Provisions for police and fire protection.
- Maintenance of public health systems.
- Operation of utilities.
- Plans adopted for the specific needs of the individual community.

During a disaster, local government assumes primary importance because it is the only authority in the affected area. At such times the local EOC has increased authority to take emergency actions, such as:

- Control movement of people.
- Control access to areas and enforce curfews.
- Control supply and rationing of food and supplies.
- Commandeer equipment and vehicles when necessary.
- Operate shelters in cooperation with the American Red Cross.
- Manage the situation as well as possible, suspending civil law if necessary.

PREPARATION BY CITIZENS

Ultimately, the responsibility for hurricane preparedness lies with you, the individual. When a storm is brewing in the Gulf, local officials are preparing for the emergency and cannot assist you with planning or background information. So know the dangers and be prepared for them before hurricane season begins.

First, determine if you are in a vulnerable area. What is the elevation of your home above sea level? How far are you from the coast? What is the maximum storm surge height that could occur in your area? Is your area susceptible to freshwater flooding? The elevation may be included on the construction plan or plat of your house. If you do not know, see Appendix VII, Part 4, for instructions. If the elevation of your house is less than 25 feet above mean sea level and you are less than 20 miles from the coast, then you could be highly susceptible to flooding by the storm surge. The nearest National Weather Service Office has estimates of the highest potential storm surge for each point along the coast and the approximate extent of inland flooding. The Office also can supply flood stage information for streams and bayous.

Second, insure your house and possessions. Purchase insurance from a reputable company and request coverage for all types of hurricane damage. In the past, some policies did not cover damage caused by rising or windblown water.

Third, know what to do in and around your house to minimize damage. A few precautions can reduce your losses. Check where to go if you are forced to evacuate and know what to take with you. Local EOC officials can supply this information. Appendix VI contains checklists and advice about preparing for a hurricane, remaining at home, and evacuating to safety.

ENDURING THE STORM

When the storm arrives with its fierce winds and driving rains, everyone must seek protection. If your planning has been thorough, there is not much to do except wait for the storm to pass.

During passage of the storm, help may not be able to reach the stricken area. People in public shelters or private homes will have to care for themselves. Here are some precautions and suggestions:

- Someone should stay awake at all times to monitor radio broadcasts and serve as guard against fire, snakes, and other hazards.
- Keep a window partially open on the downwind side of the house to stabilize pressure inside the house. This will help reduce the risk of windows or doors being blown out due to large pressure differences caused by the storm.
- Remain inside until the storm passes; do not venture outside during passage of the eye except for necessary repairs that can be accomplished quickly. Remember, the calm winds associated with the eye seldom last more than 20 minutes.
- Several people should know where emergency supplies and equipment are stored.

PICKING UP THE PIECES

While a hurricane is in progress, excitement, apprehension, fear, and thoughts of survival leave little time for despondency. After the hurricane passes, however, the extent of property damage can cause widespread shock.

Buildings may be leveled, and areas may remain flooded

Fig. 32. National Guardsmen control the entrance into a disaster area at Palacios after Hurricane Carla, September 1961. These houses were floated onto the highway by high waters. Photo courtesy of the Texas Highway Department.

for days or weeks. Roads, bridges, and highways may be impassable. Communications, utility, and public sewage systems may be disrupted severely. Health hazards abound. Private wells and municipal waterworks can be contaminated, and drinking water may not be available. Without electricity for refrigeration, foods may be inedible.

United States Public Law 93-288 provides for immediate federal assistance to hurricane-damaged areas that have been declared a "major disaster area" by the President. This declaration is made at the request of the state Governor, who is advised by county EOC officials. The Federal Disaster Assistance Administration, in the Department of Housing and Urban Development, can allot federal funds for repairing property and minimizing health hazards, including removal of debris. Manpower supplied by the military services and heavy equipment such as bulldozers can be provided. The U.S. Corps of Engineers may be summoned if local resources are exhausted.

In cooperation with state and local health officials, federal food and drug teams survey the health situation in affected areas. Contaminated foods and drugs must be destroyed. The National Disaster Control Agency and the U.S. Public Health Service assess the danger of infectious diseases and possible epidemics. Drinking water is checked by laboratory tests, and vaccines are distributed to prevent typhoid, diphtheria, and other communicable diseases.

The U.S. Department of Agriculture, through service organizations and state welfare departments, provides surplus foods for families and emergency supplies for livestock feeding. The American Red Cross gives grants, based on need (not loss), to assist families during the disaster period. In addition, the Red Cross and the Texas Division of the Salvation Army distribute food and materials from mobile canteens during and immediately after hurricanes. Funds and other assistance also may come from charitable foundations, churches, clubs, and private citizens.

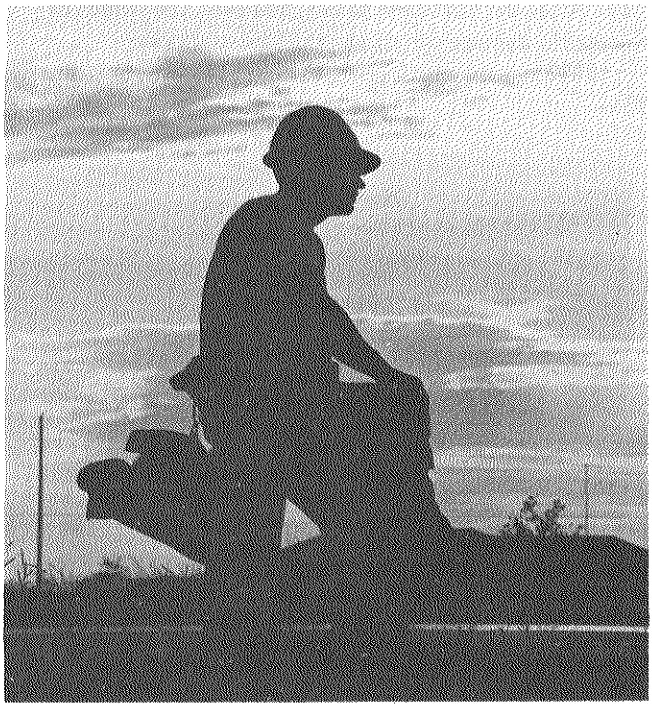


Fig. 33. A weary electric power line crewman takes a break during the recovery period from Hurricane Carla, September 1961, at Bay City. Photo courtesy of the Texas Highway Department.

The Texas National Guard, the Texas State Guard, and units of the United States Army, Navy, Air Force, and Coast Guard may aid affected communities. After a severe storm, Guard units maintain civil order, direct traffic, establish roadblocks, provide manpower for transportation, and distribute food, clothing, and other supplies. Regular military units, which also assist in these tasks, are requested when authorities feel that local resources are inadequate.

Insurance companies usually send extra adjusters to a disaster area to help process insurance claims. Many insurance companies will make an advance payment on proof of loss of identified items without requiring final adjustment. This partial payment allows time to determine total loss and to make a suitable settlement under less hectic conditions.

The primary responsibility for recovery and rehabilitation of hurricane-stricken areas, however, lies with the state governmental chain extending from the Governor through the Defense and Disaster Relief Council to local civil authorities. County-level agencies can request assistance from state and federal agencies when local resources are inadequate.

County or municipal organizations are expected to arrange for the disposition of dead animals, clearing of debris, and repair of water and sewage systems, roads, bridges, and public buildings. Local civil authorities help coordinate state, federal, private, and military efforts. Restoration of public utilities is handled by local repair crews, but utility companies outside the disaster area are called if needed. The record of these companies in quickly restoring such vital services as electricity, natural gas, and telephone lines is commendable.

IT'S YOUR RESPONSIBILITY!

Hurricanes and tropical storms will continue to hit the Texas coast, and each one is a potential killer. Even with increased standards of construction, some degree of damage must be expected. However, good planning and preparation are the surest means of reducing the number of casualties and the amount of property damage. State, federal, military, and civilian agencies or organizations will be able to provide help during natural disasters, but the ultimate responsibility for your survival and for your family's survival lies with *you*.

APPENDIX I

Hurricane terms are defined in the following glossary.

Bulletin: A public release from a Weather Service Hurricane Warning Office issued at times other than those when advisories are required. A bulletin is similar in form to an advisory but includes additional general newsworthy information.

Cautionary Advice to Small Craft: When a hurricane is within a few hundred miles of a coastline, small craft operators are warned to take precautions and to avoid entering the open sea.

Cyclone: A closed system of cyclonic (counterclockwise direction) circulation characterized by low pressure and inclement weather.

Extreme Hurricane: A tropical cyclone with maximum winds of 136 m.p.h. (118 knots) or higher and minimum central pressure of 28.00 inches Hg (711.20 mm Hg or 948.19 mb) or less.

Eye: The roughly circular area of comparatively light winds and fair weather at the center of a hurricane.

Gale Warning: A notice added to small craft advisories when winds of 38-55 m.p.h. are expected.

Hurricane: A tropical cyclone with sustained winds of 74 m.p.h. (64 knots) or greater.

Hurricane Warning: A warning that within 24 hours or less a specified coastal area may be subject to (a) sustained winds of 74 m.p.h. (64 knots) or higher and/or (b) dangerously high water or a combination of dangerously high water and exceptionally high waves, even though winds expected may be less than hurricane force.

Hurricane Watch: The first alert when a hurricane poses a possible, but as yet uncertain, threat to a certain coastal area, or when a tropical storm threatens the watch area and has a 50-50 chance of intensifying into a hurricane. Small craft advisories are issued as part of a hurricane watch advisory.

Land Subsidence: The sinking of the land, caused mainly by the withdrawal of underground water from wells supplying cities and industries. This phenomenon may cause coastal areas to become more vulnerable to tropical storm flooding.

Local Action Statement: A public release prepared by a Weather Service Office in or near a threatened area giving specific details for its area of responsibility on weather conditions, evacuation notices, and other precautions necessary to protect life and property.

Major Hurricane: A tropical cyclone with maximum winds of 101 m.p.h. to 135 m.p.h. (88 to 117 knots) and a minimum central pressure of 28.01 to 29.00 inches Hg (711.45 to 736.60 mm Hg or 948.53 to 982.05 mb).

Seiche: A series of fast-moving waves that sometimes are superimposed upon the storm surge. This phenomenon may cause total destruction and great loss of life.

Storm Surge: An abnormal rise in the level of the sea produced by the hurricane. This inundation is usually responsible for the greatest loss of life and destruction of property.

Storm Warning: A notice added to small craft advisories when winds of 56-73 m.p.h. are expected. Both gale and storm warnings indicate the coastal area to be affected and the expected intensity of the disturbance.

Tornado: A violently rotating column of air, nearly always observable as a funnel cloud.

Tornado Forecast Information: An advisory stating that conditions are such that tornadoes may occur.

Tornado Warning: An advisory stating that a tornado actually has been sighted by human eye or indicated by radar.

Tropical Cyclone: A general term for the nearly circular cyclones that originate over tropical oceans. It includes tropical storms, tropical depressions and all types of hurricanes.

Tropical Cyclone/Hurricane Advisories: Messages issued simultaneously by the Hurricane Warning Offices and the National Hurricane Center in Miami every six hours describing the storm, its position, anticipated movement, and prospective threat.

Tropical Depression: A tropical cyclone with sustained winds of less than 39 m.p.h. (34 knots).

Tropical Storm: A tropical cyclone with sustained winds of 39 to 73 m.p.h. (34 to 63 knots).

APPENDIX II

A chronological listing of the Tropical Cyclones which affected Texas from 1871-1974 is given in Table 1. Table 2 gives a summary by month of the data presented in Table 1.

TABLE 1

A list by date of hurricanes and tropical storms which made landfall on the Texas Coast, came close enough to affect it, or entered Texas through Mexico or Louisiana:

1871	June 4	Tropical Storm made landfall near Galveston
	June 9	Tropical Storm made landfall near Galveston
	October 2	Hurricane passed near central Texas coast
1874	July 4	Hurricane made landfall near Indianola
	September 4	Tropical Storm moved into Texas from Mexico
1875	September 16	Hurricane decimated Indianola
1877	September 16	Hurricane passed near entire Texas coast
1879	August 22	Tropical Storm moved inland near High Island
1880	June 24	Hurricane moved inland near Victoria
	August 12	Hurricane passed near lower Texas coast
1881	August 13	Hurricane made landfall near Corpus Christi
1885	September 18	Hurricane passed near lower Texas coast
1886	June 14	Tropical Storm passed near central and upper Texas coast
	August 20	Hurricane decimated Indianola, town never rebuilt
	September 22	Hurricane moved inland near Brownsville
	October 12	Hurricane moved inland near Beaumont
1887	September 21	Hurricane made landfall near Brownsville
1888	June 16	Hurricane made landfall near Matagorda
	July 5	Tropical Storm made landfall near Matagorda
1891	July 5	Hurricane moved inland near Matagorda
1895	August 29	Hurricane moved inland near Brownsville
	October 6	Tropical Storm moved inland near Galveston
1897	September 12	Hurricane moved into Texas from Louisiana
1898	September 27	Tropical Storm moved inland near Galveston
1900	September 8	Hurricane decimated Galveston, worst weather disaster in U.S. history
1901	July 10	Tropical Storm moved inland near Victoria
1902	June 26	Hurricane made landfall near Victoria
1909	June 30	Tropical Storm moved inland between Corpus Christi and Brownsville
	July 21	Hurricane made landfall south of Galveston
	August 27	Hurricane made landfall south of Brownsville
1910	August 31	Tropical Storm made landfall south of Brownsville
	September 14	Hurricane made landfall between Corpus Christi and Brownsville
1912	October 16	Hurricane made landfall between Corpus Christi and Brownsville
1913	June 27	Hurricane made landfall between Corpus Christi and Brownsville

1914	September 19	Tropical Storm moved into Texas from Louisiana
1915	August 17	Hurricane made landfall near Matagorda
1916	August 18	Hurricane made landfall near Corpus Christi
1918	August 6	Hurricane made landfall east of Beaumont in Louisiana
1919	September 15	Hurricane moved inland just south of Corpus Christi
1921	June 22	Hurricane made landfall near Victoria
1925	September 6	Tropical Storm moved inland near Brownsville
1926	August 27	Tropical Storm moved into Texas from Louisiana
	September 22	Tropical Storm moved into Texas from Louisiana
1929	June 28	Hurricane moved inland between Victoria and Corpus Christi
1931	June 27	Tropical Storm moved inland near Corpus Christi
1932	August 13	Hurricane moved inland near Galveston
1933	July 22	Tropical Storm made landfall near Matagorda
	August 4	Hurricane moved inland near Brownsville
	September 4	Hurricane moved inland near Brownsville
1934	July 25	Hurricane moved inland near Corpus Christi
	August 27	Hurricane passed near entire Texas coast
1936	June 27	Hurricane made landfall near Corpus Christi
	September 13	Tropical Storm moved inland near Brownsville
1938	August 14	Hurricane moved into Texas from Louisiana
	October 17	Tropical Storm made landfall near Matagorda
1940	August 7	Hurricane made landfall at Texas-Louisiana border
	September 23	Tropical Storm passed near upper Texas coast
1941	September 14	Tropical Storm made landfall near High Island
	September 23	Hurricane moved inland near Matagorda
1942	August 21	Hurricane moved inland at Galveston
	August 29	Hurricane moved inland at Corpus Christi
1943	July 27	Hurricane made landfall at Galveston
	September 27	Hurricane passed near lower Texas coast
1945	July 21	Tropical Storm moved inland south of Corpus Christi
	August 27	Hurricane moved inland near Victoria
1946	June 16	Tropical Storm moved inland near Beaumont
1947	August 1	Tropical Storm moved inland near Brownsville
	August 24	Hurricane made landfall at Galveston
	September 19	Tropical Storm moved into Texas from Louisiana
1949	October 3	Hurricane made landfall near Matagorda
1954	June 25	Hurricane Alice made landfall south of Brownsville and moved up the Rio Grande
	July 29	Tropical Storm Barbara moved into Texas from Louisiana
1955	August 2	Tropical Storm Brenda moved into Texas from Louisiana
	August 27	Tropical Storm moved into Texas from Louisiana
1957	June 27	Hurricane Audrey made landfall just east of the Texas-Louisiana border
	August 9	Tropical Storm Bertha made landfall at the Texas-Louisiana border

1958	June 15	Tropical Storm Alma made landfall south of Brownsville and moved up the Rio Grande
	September 6	Tropical Storm Ella made landfall near Corpus Christi
1959	July 25	Hurricane Debra moved inland at Galveston
1960	June 24	Tropical Storm moved inland near Corpus Christi
1961	September 11	Hurricane Carla moved inland near Victoria
1963	September 17	Hurricane Cindy made landfall near High Island
1964	August 7	Tropical Storm Abby moved inland near Matagorda
1967	September 20	Hurricane Beulah moved inland between Brownsville and the mouth of the Rio Grande
1968	June 23	Tropical Storm Candy made landfall near Corpus Christi
1970	August 3	Hurricane Celia moved inland at Corpus Christi
	September 16	Tropical Storm Felice moved inland near Galveston
1971	September 10	Hurricane Fern moved inland near Matagorda
	September 14	Hurricane Edith passed near entire Texas coast
1973	September 5	Tropical Storm Delia moved inland between Galveston and Matagorda
1974	September 9	Hurricane Carmen made landfall in Louisiana and moved into Texas as a Tropical Storm

TABLE 2

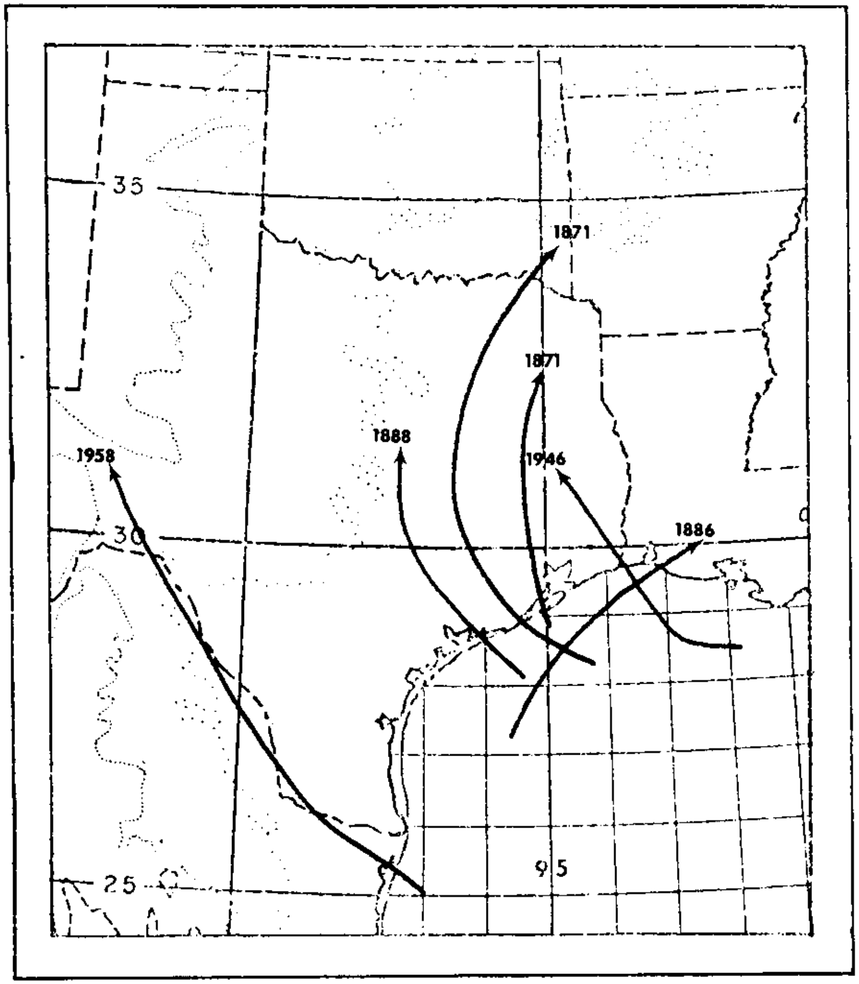
Table 2 contains the total number by month of hurricanes or tropical storms that hit the Texas coast, moved into Texas from Mexico or Louisiana, or affected the Texas coast as they passed through the Gulf of Mexico during the period from 1871 to 1976.

	June	July	August	September	October
Hurricane	7	6	13	12	3
Tropical Storm	7	4	4	8	2
Hurricane came close	2	0	5	5	1
Tropical Storm came close	2	1	4	5	0

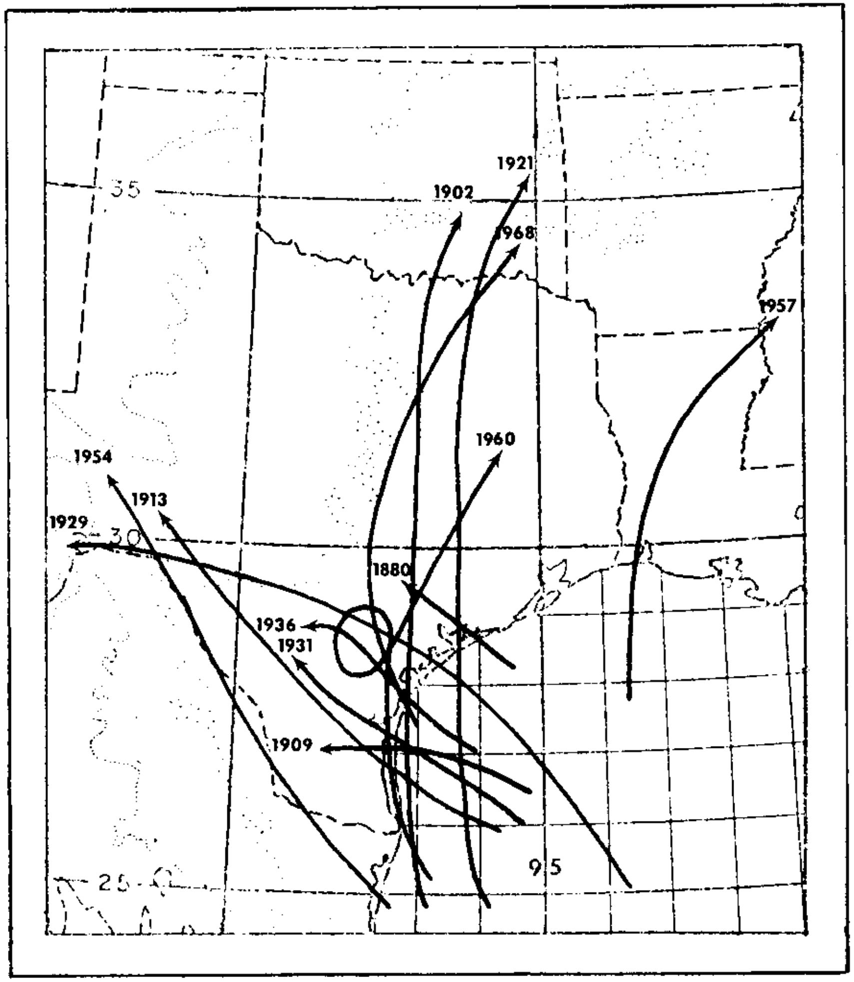
Number of years without a tropical storm or hurricane: 44

APPENDIX III

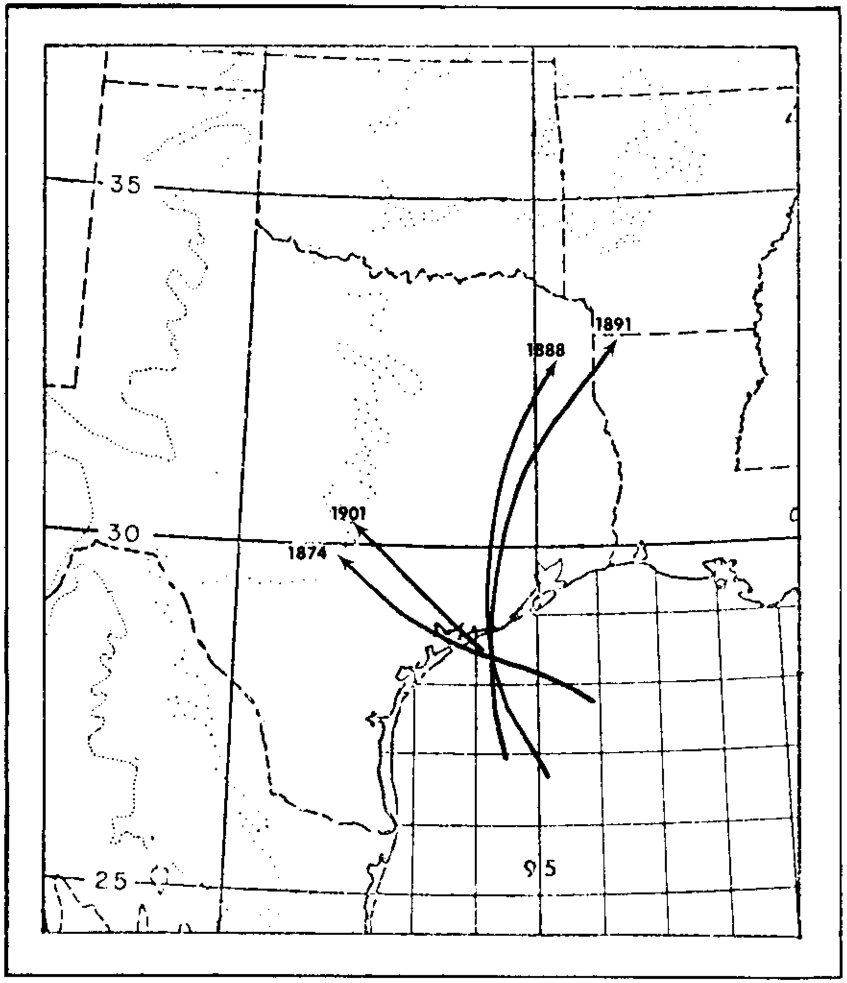
The tracks of individual tropical storms and hurricanes are shown. Tracks are separated by months and part of months. The year is indicated at the end of the track.



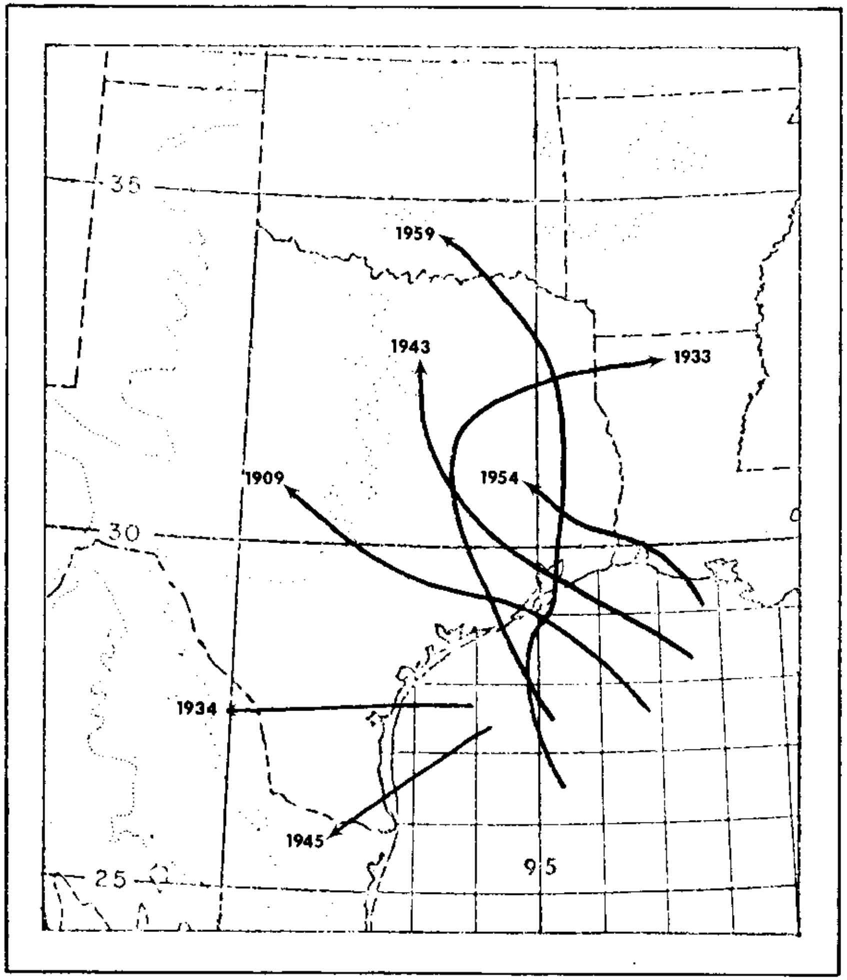
June 1-20



June 21-30

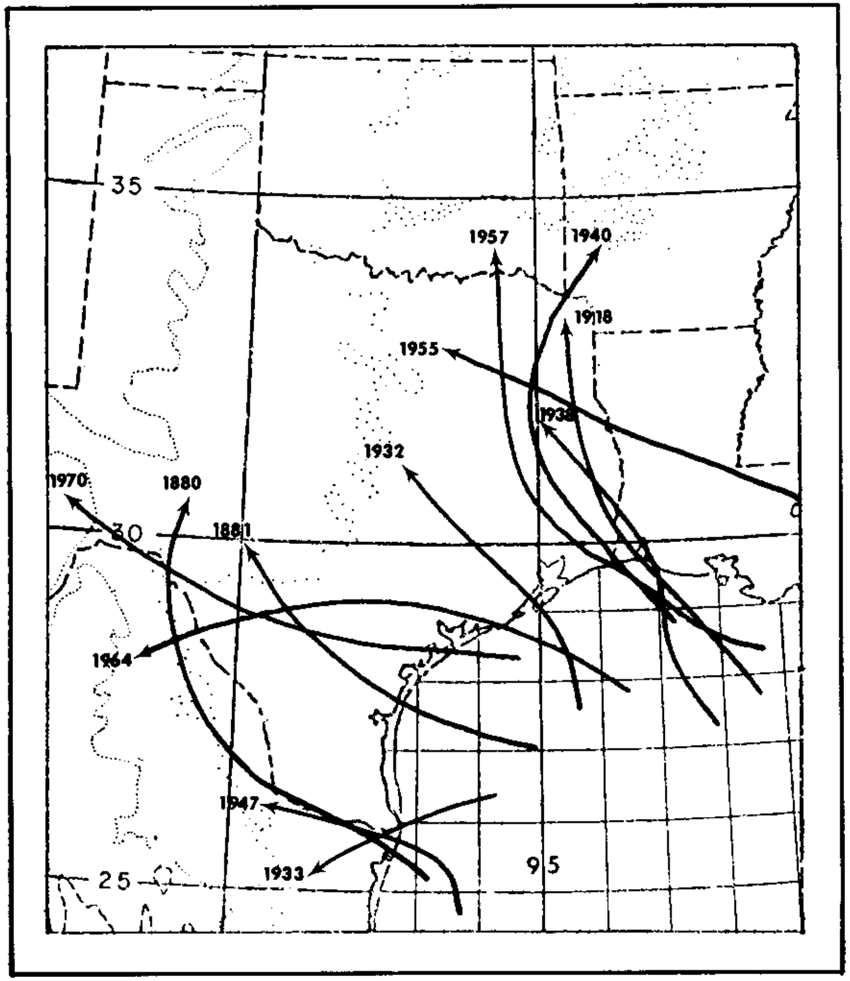


July 1-15

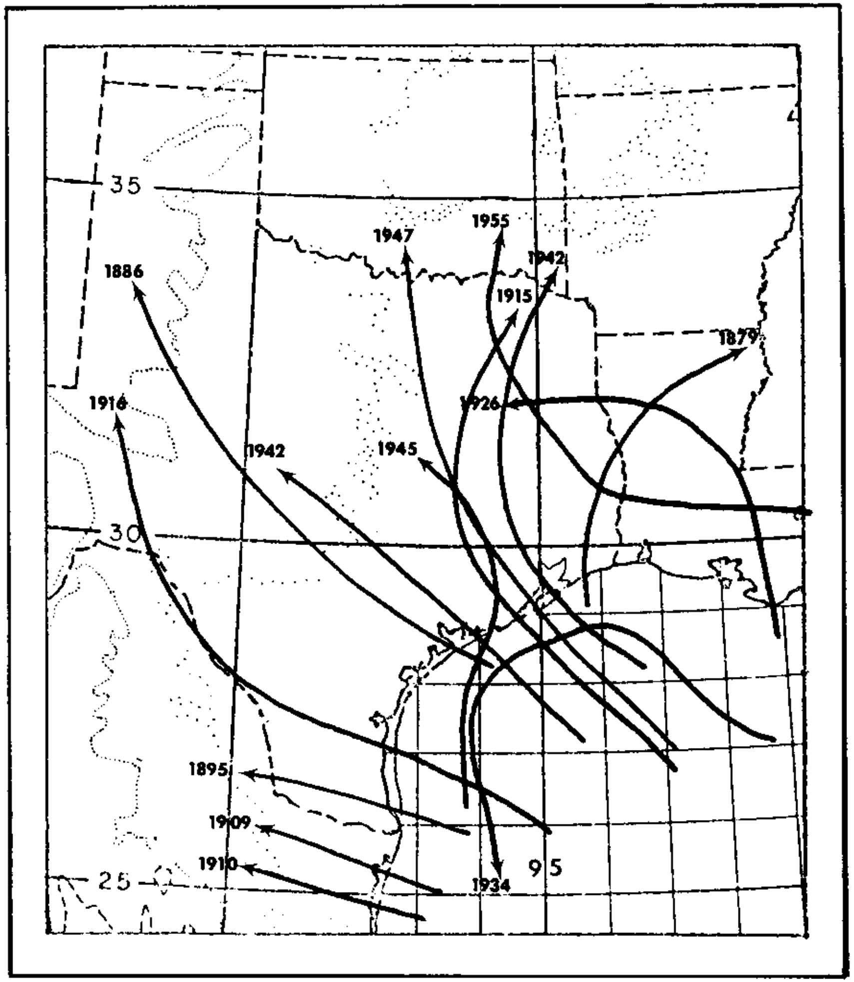


July 16-31

TROPICAL STORM AND HURRICANE TRACKS

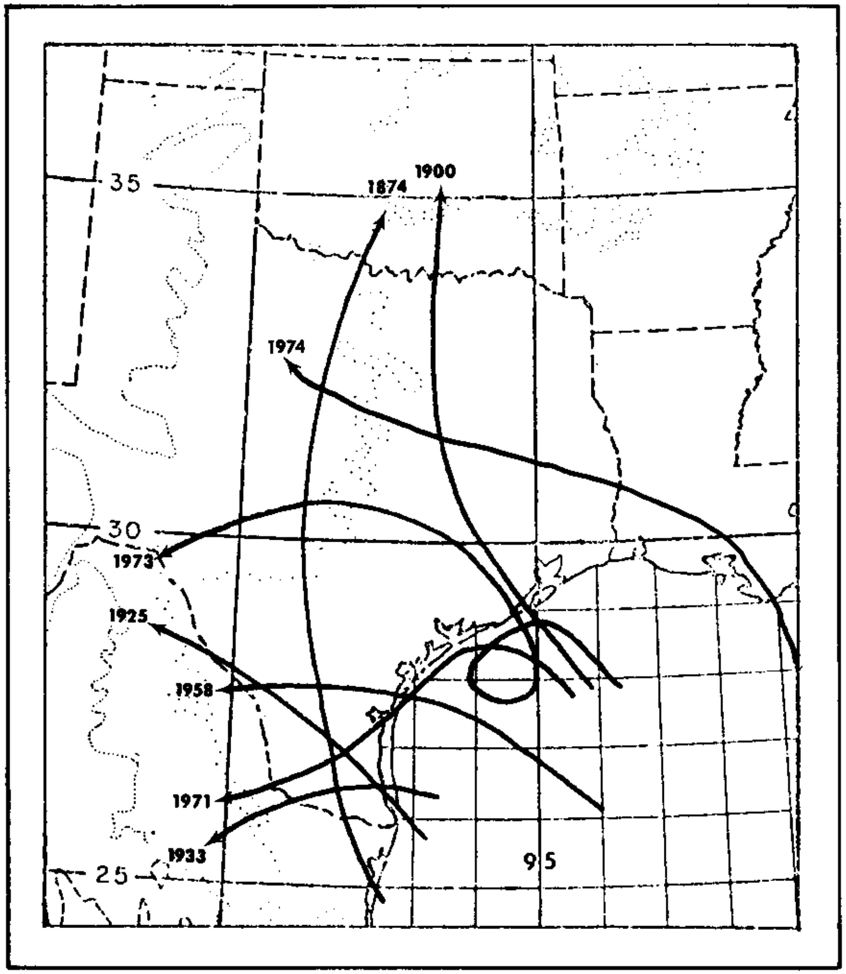


August 1-15

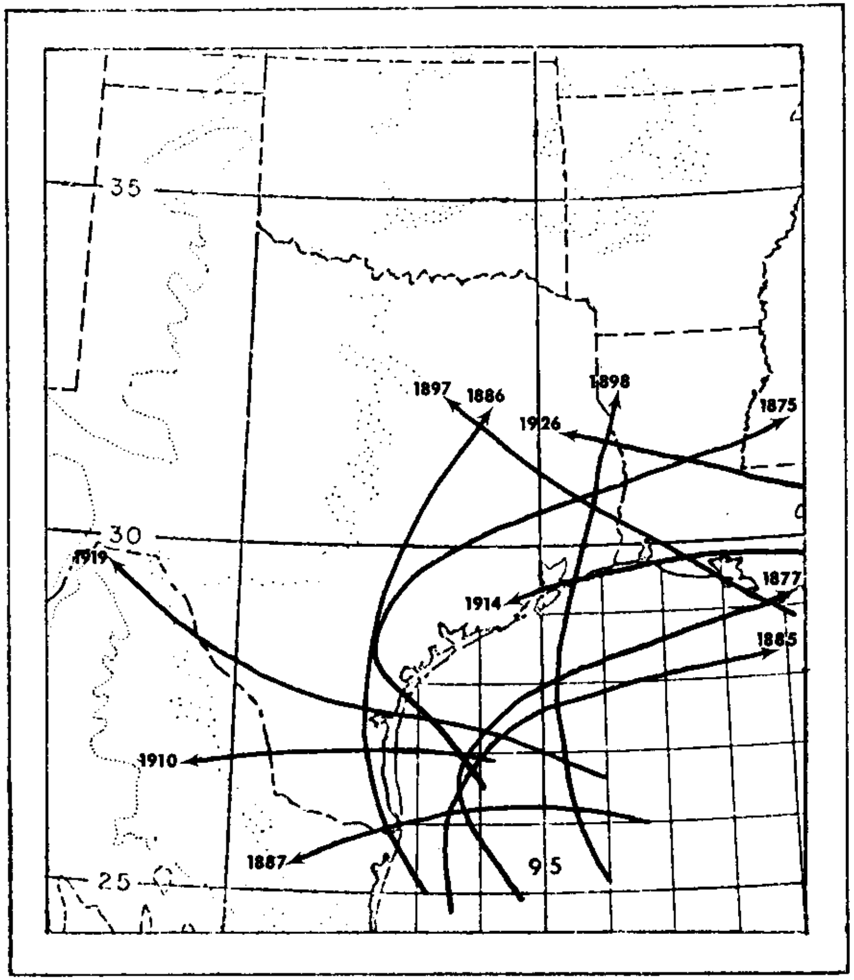


August 16-31

TROPICAL STORM AND HURRICANE TRACKS



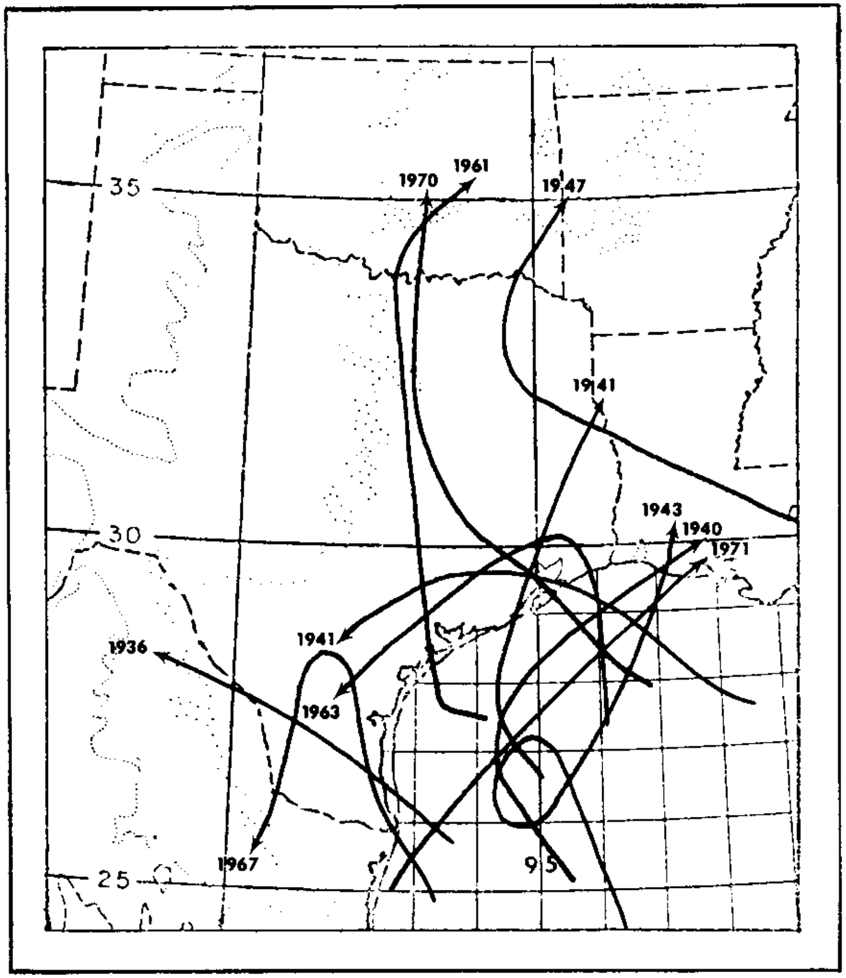
September 1-10



September 11-30

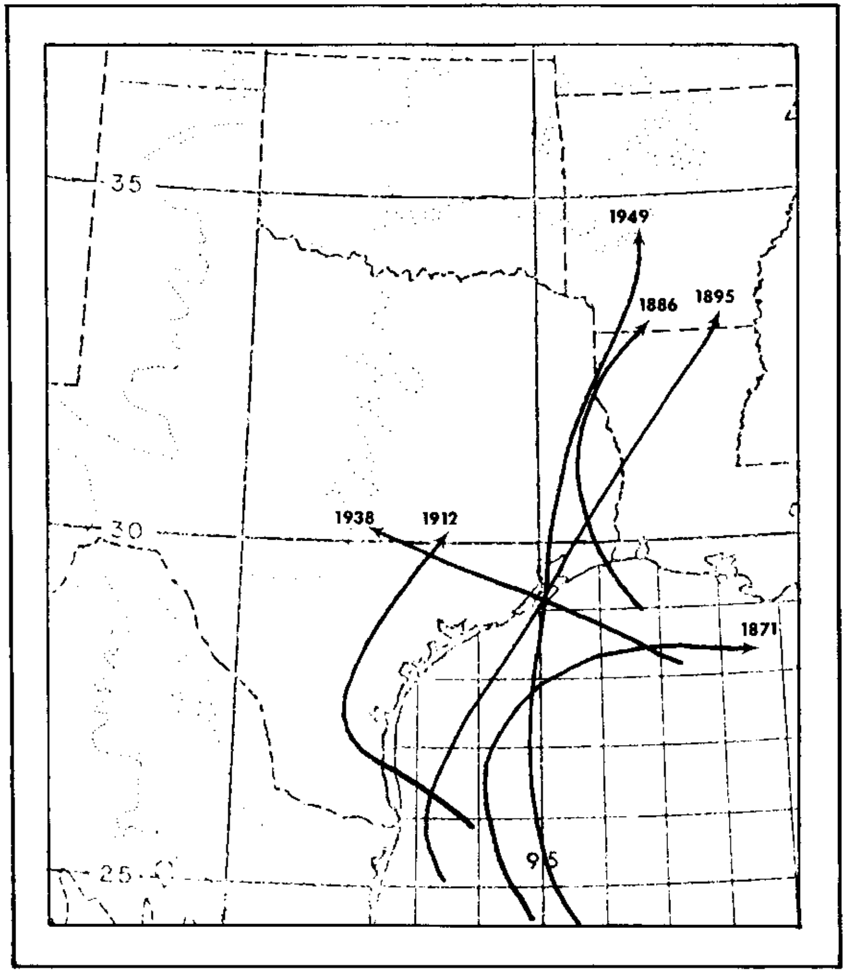
1871-1926

TROPICAL STORM AND HURRICANE TRACKS



September 11-30

1927-1973



October 1-31

TROPICAL STORM AND HURRICANE TRACKS

APPENDIX IV

This summary lists the largest number of deaths and the greatest amount of dollar damage caused by hurricanes affecting the Texas coast.

Largest Number of Deaths

Hurricane and Date	Texas Deaths	Dollar Damage
Great Galveston Hurricane 8-10 September 1900	6,000-8,000	$30-40 million
Corpus Christi Hurricane 14 September 1919	284	20 million
Galveston Hurricane 16-19 August 1915	275	56 million
Indianola Hurricane 15-18 September 1875	176	No estimate

Greatest Amount of Dollar Damage

Hurricane and Date	Texas Deaths	Dollar Damage
Celia 3-4 August 1970	11 5 outside Texas	500 million No estimate outside Texas
Carla 11-14 September 1961	34 12 outside Texas	400 million 25 million outside Texas
Beulah 8-21 September 1967	15 44 outside Texas	200 million No estimate outside Texas
Galveston Hurricane 16-19 August 1915	275	56 million No estimate outside Texas
Great Galveston Hurricane 8-10 September 1900	6,000-8,000	30-40 million No estimate outside Texas

APPENDIX V

Estimated costs of the last three extreme hurricanes are listed by type of damage.

HURRICANE	COSTS
Carla (1961)	
Damage by storm surge	$200,195,000
Damage by wind, rain, and tornadoes	203,584,000
Cost of rescue efforts	4,511,000
TOTAL	$408,290,000

Acres flooded -- 1,560,565

Beulah (1967)	
Damage by storm surge	$ 5,449,000
Damage by wind, rain, and tornadoes	46,491,000
Damage by floods (river system and flash)	108,158,000
Cost of rescue efforts	8,746,000
TOTAL	$168,844,000

5 deaths and $2 million damage by tornadoes
Acres flooded by storm surge – 630,000
Acres flooded by overflow from 50 streams -- 1,400,000

Celia (1970)	
Damage by storm surge	$ 27,570,000
Damage by wind, rain, and tornadoes	439,738,000
Cost of rescue efforts	32,692,000
TOTAL	$500,000,000

APPENDIX VI

Presented here are three hurricane-safety checklists for evaluating home safety, deciding whether or not to remain at home, and evacuating the area. Individuals are urged to use these checklists now, to review them periodically, and to share them with friends. Extra copies that may be torn out are included in the back of this booklet.

To keep these lists available, it is convenient to specify one location, such as the inside of a closet door, as the emergency center of the house. A framework can be installed to hold a first-aid kit, snake-bite kit, flashlight, candles, waterproof match box, and booklets on first aid, civil defense, tornado safety, and hurricane preparedness. A fire extinguisher is recommended. Emergency phone numbers should be listed on the door in large letters that can be read in poor light and without glasses.

A. Checklist for Evaluating Home Hurricane Safety

YES/NO

______ 1. Is your home within 20 miles of the coast?

______ 2. Is your home less than 25 feet above mean sea level?

______ 3. Is your home in an area susceptible to flash floods or river system floods?

______ 4. Do you live in a mobile home within 50 miles of the coast? If your answer is "yes," plan to evacuate your home and proceed to the evaluation checklist.

If you have answered "yes" to any questions above, complete Checklist A. Then proceed to the checklist applicable to your plans for weathering a hurricane--remaining at home or evacuating the area.

______ 5. Is your insurance coverage suitable?

______ 6. Have you stored your valuable papers, jewelry, keepsakes, etc. in a bank vault or secure place that will be safe from storms, fires, or looters?

B. Checklist for Remaining at Home during a Hurricane

YES/NO

______ 1. Are you aware that mobile homes are more susceptible to damage by high winds than other types of housing? Your mobile home should be tied at all times. When a hurricane approaches, *leave* for more substantial shelter.

_____ 2. If you own a boat, is it moored securely? Do not attempt to ride out a storm on your boat or to return to check its moorings after the storm has arrived. Small boats can be tied close to the house and filled with water to keep them from being blown away.

_____ 3. Do you have a full tank of gasoline in your car? Authorities may advise you to evacuate if conditions worsen and your home is no longer safe. If electric power is off, filling stations may not be able to operate pumps for several days.

_____ 4. Have you stored or secured outdoor objects that could be blown away or uprooted? Garbage cans, garden tools, awnings, TV antennas, signs, outdoor furniture, and toys can become lethal projectiles in hurricane-force winds.

_____ 5. Are windows boarded or shutters in place? (Use good lumber and make sure it is fastened securely. Makeshift boarding or plywood may come apart when wet and do more damage than not having taken any precautions.)

_____ 6. Do you have strong bracing for outside doors?

_____ 7. Are flashlights and/or emergency lights working? Do you have extra batteries?

_____ 8. Do you have a sufficient supply of drinking water on hand? Since city water service may be interrupted, you should sterilize the bathtub, jugs, bottles, pots and pans, then fill them with water. Water in the hot water tank may be used for drinking. A supply of water purification tablets is recommended.

_____ 9. Have you stocked non-perishable food that does not need refrigeration and can be eaten without cooking or with little preparation? Remember that electric power may be off and you may be without refrigerator or stove.

_____ 10. Do you have sufficient medication and prescription drugs?

_____ 11. Do you have a portable radio in working condition so that you can listen to local stations for storm watches and warnings and for instructions from the local EOC?

_____ 12. Do you have an axe and wrecking bar immediately available? If the house shifts or falls, these tools may be needed to open doors or to rescue trapped individuals.

_____ 13. Have you moved furniture away from exposed windows and doors? Tape windows to reduce the possibility of flying glass.

_____ 14. Do you know that it is *extremely* important to stay inside during the storm and not to go out during the lull while the eye is passing?

_____ 15. Do you know how to shut off the main gas valve and to pull the main power switch if the house starts to flood? Flooding will extinguish pilot lights and gas may leak. High water can cause shorting of electric lines, which could start fires. It is unlikely that help will be available to control or extinguish fires.

_____ 16. Are you aware of the dangers (flying debris) of opening a door or window on the windward side of the house? Exit on the downwind side if possible.

_____ 17. Are you prepared to evacuate if required? Take only necessary clothing. (It is advisable to have a suitcase packed.) See Appendix VII, Part 5.

_____ 18. If you have to evacuate at the last minute, do you know which evacuation route to use? Keep up-to-date on the best route by listening to the radio in your area.

a. Use route_______to_____________.

b. Use route_______to_____________.

c. Use route_______to_____________.

_____ 19. Do you have the location and telephone number of the nearest Red Cross shelter posted in your house? Information will be given over radio concerning *available* shelters. Remember that the list may not include the shelter closest to your home.

a. Address______________Phone____

b. Address______________Phone____

c. Address________________Phone____

______ 20. Do you know that downed electric power lines are *extremely* dangerous? Do not move or touch them.

C. Checklist for Evacuating the Area

If you decide to evacuate, try to leave during daylight hours well in advance of the storm. Heavy rains and high winds usually precede the storm by six hours.

YES/NO

______ 1. Have you tied down your mobile home? See Appendix XII.

______ 2. Is a car with a full tank of gasoline ready if needed? Walk to shelter when possible to help alleviate traffic congestion.

______ 3. If you own a boat, is it moored securely? (Do not attempt to ride out a storm on your boat or to return to check its moorings after the storm arrives.) Small boats can be tied next to the house and filled with water to keep them from being blown away.

______ 4. Have you stored or secured outdoor objects that might be blown away? Garbage cans, garden tools, awnings, TV antennas, signs, outdoor furniture, and toys can become lethal projectiles in hurricane-force winds.

______ 5. Are windows boarded or shutters in place? Taping windows helps to reduce flying glass.

______ 6. Do you have strong bracing for outside doors?

______ 7. Have you moved furniture away from exposed windows and doors?

______ 8. Do you have sufficient prescription drugs or medicines?

______ 9. Have you taken only necessary clothing? See Appendix VII, Part 5.

______ 10. Have you shut off the main gas valve and pulled the main power switch before leaving?

______ 11. Do you know that downed electric power lines are extremely dangerous? Do not move or touch them.

______ 12. Are you familiar with the best evacuation route to use?

a. Use route________to______________.

b. Use route________to______________.

c. Use route________to______________.

______ 13. If you are marooned, do you know the location and telephone number of your nearest Civil Defense or Red Cross shelters?

a. Address________________Phone____

b. Address________________Phone____

c. Address________________Phone____

APPENDIX VII

General information that may be useful in preparing for a hurricane is presented here.

1. *Device for protecting windows.* Scientists at Texas A&M University have designed a protective device for windows This 10-inch aluminum disc, when clamped onto windows with an aluminum bar, is said to enable windows to withstand winds up to 240 miles per hour. This device is better protection than boards or shutters and is easier to install. It is recommended for upper-story windows, which are affected less by flying debris. Ground-level windows should be boarded. For further information about this disc, write to Dr. John Reading, Physics Department, Texas A&M University, College Station, TX 77843

2. *Tiedown for mobile homes.* If you live in a mobile home, you should be prepared to evacuate. However, your mobile home should be tied throughout the year. A booklet entitled "Protecting Mobile Homes from High Winds" can be obtained from your local Civil Defense office or by writing the U.S. Army AG Publications Center, Civil Defense Branch, 2800 Eastern Blvd., Baltimore, MD 21220. Appendix XII contains an excerpt from this booklet.

3. *Maps of areas covered by storm surges of previous hurricanes.* "Hurricane Awareness Program Materials" may be obtained from the Texas Coastal and Marine Council, P.O. Box 13407, Austin, TX 78711. Included in these materials are maps showing the extent of storm surge flooding from past hurricanes. Storm evacuation maps may be obtained from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Distribution Division, C44, Riverdale, MD 20840. These maps, $2 each, are large scale and cover a small area in great detail. Specify the location for the map requested. Maps are available at this time for the following areas:

Alvin	Beaumont	Galveston	Refugio
Anahuac	Corpus Christi	Houston	Rockport
Aransas Pass	Freeport	Port Arthur	Winnie

4. *Information on land elevation.* The local city engineer should be able to tell you the land elevation of an area. The engineering office in a Drainage District also has the information. The U.S. Department of Agriculture--Soil Conservation Service (USDA-SCS) can supply the information for rural as well as urban areas. There are SCS offices in the following cities:

Anahuac	Edna	Port Lavaca	San Benito
Angleton	Harlingen	Raymondville	Sinton
Bay City	Houston	Refugio	Victoria
Beaumont	Kountze	Robstown	Wharton
Edinburg	Liberty	Rosenberg	

5. *Possessions to take when evacuating.* A hurricane shelter will be the most suitable building in the area, such as a school, church, or courthouse. Rooms and halls will be lined with folding cots. Foods will be simple and rationed. Privacy will be minimal, and all refugees must help to maintain public health and sanitation. With *good humor* and *cooperation* everyone can endure, and many lasting friendships may begin under such conditions. Expect to remain in the shelter one to three days. When evacuating to a shelter, take:

- One change of durable clothing (heavy shoes, work clothes, etc.).
- Special medicine the family needs.
- Special food any family member requires.
- Special clothes for babies, especially disposable diapers.
- Extra eye glasses if needed.
- Minimal toilet articles.
- Paper towels, kleenex, etc.
- Bedding, if time and space permit.

Do not take:

- Alcoholic beverages.
- Firearms, other weapons, or fireworks.
- Family pets. (Do not leave pets tied or confined. However, if you do not wish to leave your pet to fend for itself, evacuate from the area and place the animal in commercial facilities.)

When evacuating to a known place (i.e., the home of a relative or friend), take:

- Medication the family requires.
- Extra eyeglasses if needed.
- Durable work clothes for returning to the disaster area to make house repairs.

When returning to the disaster area, leave young children and pets behind, if possible, until utilities and public services (drinking water, etc.) are restored and until home repairs and cleanup have been completed.

6. *Evacuation vehicle.* Take a vehicle in good mechanical condition since repairs and services may not be available. A larger car is preferable because it will drive through deeper water, will not be blown off the road as easily as a smaller car, and will carry more people and items. Do not overload, however. Water on the road may cause brakes to malfunction and the engine to stall. Traffic may be bumper-to-bumper so demonstrate your best driving skill and judgment on the evacuation trip. A motorcycle should be used only as a last resort.

APPENDIX VIII

Listed here are names of Atlantic hurricanes and tropical storms for the period 1975-1984. Each set of names is repeated every 10 years. In the event of an extremely damaging hurricane, that name is retired permanently and a new name is substituted.

1975--Amy, Blanche, Caroline, Doris, Eloise, Faye, Gladys, Hallie, Ingrid, Julia, Kitty, Lilly, Mabel, Niki, Opal, Peggy, Ruby, Sheila, Tilda, Vicky, Winnie.

1976--Anna, Belle, Candice, Dottie, Emmy, Frances, Gloria, Holly, Inga, Jill, Kay, Lilias, Maria, Nola, Orpha, Pamela, Ruth, Shirley, Trixie, Vilda, Wynne.

1977--Anita, Babe, Clara, Dorothy, Evelyn, Frieda, Grace, Hannah, Ida, Jodie, Kristina, Lois, Mary, Nora, Odel, Penny, Raquel, Sophia, Trudy, Virginia, Willene.

1978--Amelia, Bess, Cora, Debra, Ella, Flossie, Greta, Hope, Irma, Juliet, Kendra, Louise, Martha, Noreen, Ora, Paula, Rosalie, Susan, Tanya, Vanessa, Wanda.

1979--Angie, Barbara, Cindy, Dot, Eve, Franny, Gwyn, Hedda, Iris, Judy, Karen, Lana, Molly, Nita, Ophelia, Patty, Roberta, Sherry, Tess, Vesta, Wenda.

1980--Abby, Bertha, Candy, Dinah, Elsie, Felicia, Georgia, Hedy, Isabel, June, Kim, Lucy, Millie, Nina, Olive, Phyllis, Rosie, Suzy, Theda, Violet, Willette.

1981--Arlene, Beth, Chloe, Doria, Edith, Fern, Ginger, Heidi, Irene, Janice, Kristy, Laura, Margo, Nona, Orchid, Portia, Rachel, Sandra, Terese, Verna, Wallis.

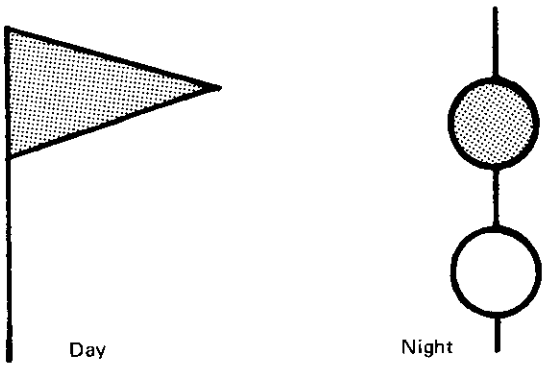
1982--Agnes, Betty, Carrie, Dawn, Edna, Felice, Gerda, Harriet, Illene, Jane, Kara, Lucile, Mae, Nadine, Odette, Polly, Rita, Sarah, Tina, Velma, Wendy.

1983--Alice, Brenda, Christine, Delia, Ellen, Fran, Gilda, Helen, Imogene, Joy, Kate, Loretta, Madge, Nancy, Ona, Patsy, Rose, Sally, Tam, Vera, Wilda.

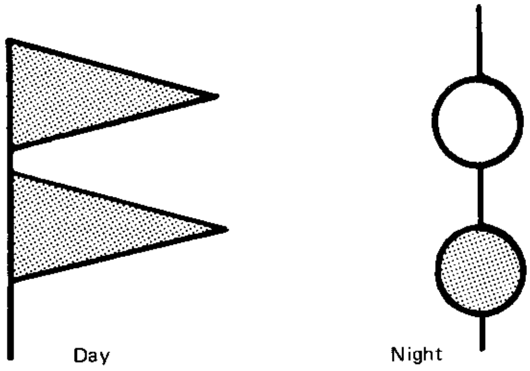
1984--Alma, Becky, Carmen, Dolly, Elaine, Fifi, Gertrude, Hester, Ivy, Justine, Kathy, Linda, Marsha, Nelly, Olga, Pearl, Roxanne, Sabrina, Thelma, Viola, Wilma.

APPENDIX IX

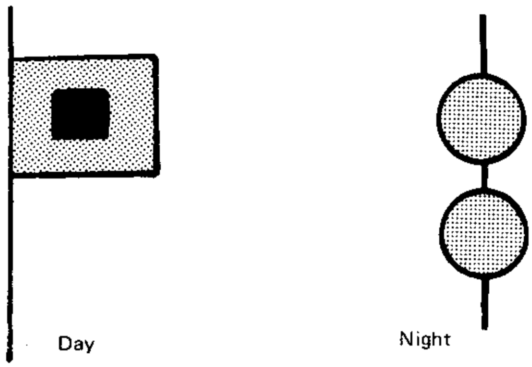
Colored pennants and lights are displayed in some ports and areas of the Texas coast to warn of hazardous sea conditions. Modern technology, however, has reduced the number of flag stations needed along the coast. Now emphasis is placed on continuous marine broadcasts transmitted at 162.55 MHz.



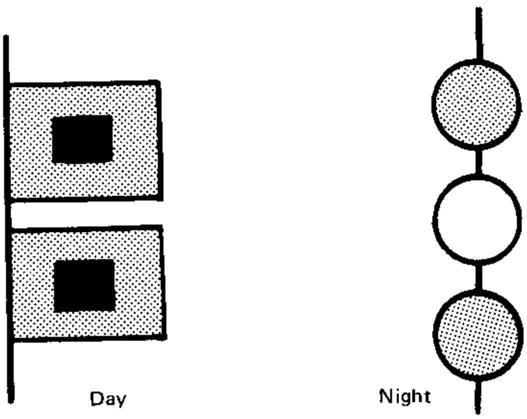
Small Craft Advisory. One RED pennant displayed by day and a RED light over a WHITE light at night to indicate the winds and seas, or sea conditions alone, considered dangerous to small craft operations are forecast. Winds may range as high as 38 m.p.h. (33 knots.)



Gale Warning. Two RED pennants displayed by day and a WHITE light above a RED light at night to indicate winds within the range 39 to 54 m.p.h. (34 to 47 knots) are forecast for the area.



Storm Warning. A single square RED flag with a BLACK center displayed during daytime and two RED lights at night to indicate winds within the range 55 to 73 m.p.h. (48 to 63 knots) are forecast for the area.



Hurricane Warning. Two square RED flags with BLACK center displayed during the day and WHITE light between two RED lights at night to indicate that winds 74 m.p.h. (64 knots) and above are forecast for that area.

APPENDIX X

The following excerpt is reprinted from *NOAA Magazine*, Volume 4, Number 3, July 1974.

Hurricane Disaster-Potential Scale:*

The hurricane disaster-potential scale is an experimental effort by the National Weather Service to give public safety officials a continuing assessment of the potential for wind and storm-surge damage from a hurricane after it reaches a point where it could be a threat to their coastal populations.

Scale numbers are made available to public-safety officials when a hurricane is within 72 hours of landfall.

Scale numbers range from 1 to 5--with Scale No. 1 having at least the threshold windspeed of a hurricane of 74 miles per hour, or a storm surge 4 to 5 feet above normal water level--and Scale No. 5 having a windspeed of 155 miles per hour or more, or a storm surge more than 18 feet above normal.

The Weather Service emphasizes that the disaster-potential numbers are not forecasts, but will be based on observed conditions at a given time in a hurricane's lifespan. They represent an estimate of what the storm would do to a coastal area if it were to strike without change in destructive power. Scale assessments will be revised regularly as new observations are made, and public-safety organizations will be continually advised of new estimates of the hurricane's disaster potential.

The Disaster-Potential Scale gives probable property damage and evacuation recommendations as follows:

Scale No. 1--Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage and unanchored mobile homes. No real damage to other structures. Some damage to poorly constructed signs. **Or**: storm surge 4 to 5 feet above normal. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorages torn from moorings.

Scale No. 2--Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage, some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. **Or**: storm surge 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying island areas required.

Scale No. 3--Winds of 111 to 130 miles per hour. Foliage torn from trees, large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. **Or**: storm surge 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required.

Scale No. 4--Winds of 131 to 155 miles per hour. Shrubs and trees blown down, all signs down. Extensive damage to roofing materials, windows and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. **Or**: storm surge 13 to 18 feet above normal. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before

Definition of the Scale

Category	Central Pressure (millibars)	Winds (mph)	Surge (ft)	Example
1	> 980	74-95	4-5	Agnes 1972 (Fla. coast)
2	965-979	96-110	6-8	Cleo 1964
3	945-964	111-130	9-12	Betsy 1965
4	920-944	131-155	13-18	Donna 1960 Fla., Carla 1961 Tex.
5	< 920	> 155	> 18	1935 Storm on Fla. Keys

*Developed by Herbert Saffir, Dade County consulting engineer, and Dr. Robert H. Simpson, former National Hurricane Center Director hurricane center arrives. Major erosion of beaches. Massive evacuation of all residences within 500 yards of shore possibly required, and of single-story residences on low ground within 2 miles of shore.

Scale No. 5--Winds greater than 155 miles per hour. Shrubs and trees blown down, considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes. **Or:** storm surge greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of residential areas on low ground within 5 to 10 miles of shore possibly required.

APPENDIX XI

Food is an important item for survival and must be obtained before the disaster strikes. The food selected must meet several requirements, such as nourishment, taste, and easy preparation, perhaps without heat or refrigeration. One listing of a disaster diet has been published by the Government Printing Office. When ordering from the Public Documents Distribution Center, Pueblo, CO 81009, include the publication numbers from the following information:

> *28J DISASTER DIET.* This folder describes a Disaster Diet Kit and tells how it should be designed to provide nourishment for a family isolated from normal food sources for several days by hurricanes, floods, winter storms, etc. 1974. 8 p. $.25
> *C 55.2:D 63/2 S/N 0317-00236*

Another food list for disaster diets is being published by the Texas Agricultural Extension Service. Copies of this pamphlet will be available before the 1976 hurricane season and may be obtained at the county agent's office or by writing the Texas Agricultural Extension Service, Texas A&M University, College Station, TX 77483.

APPENDIX XII

The following excerpt is taken from *Protecting Mobile Homes From High Winds,* a 1974 publication that includes detailed information about and drawings of piers and footings, ties, and anchors for mobile homes. Specify publication TR-75 when ordering this booklet from your local Civil Defense office or from the U.S. Army AG Publications Center, Civil Defense Branch, 2800 Eastern Blvd, Baltimore, MD 21220.

Tiedown Mobile Homes for Safety

Tiedowns offer the most consistent and effective means for minimizing mobile home damage from high winds. Two types of ties are needed: (1) the "over-the-top" tie, and (2) the frame tie. The first keeps the unit from overturning, and the second prevents it from being blown off the supports.

Frame ties can also reduce the chance of overturn, but many mobile homes do not have enough internal strength to transmit high wind loads to the supporting steel frame. Thus, installation solely of frame ties will secure the frame, but the unit resting on the frame may blow away. Therefore, the Defense Civil Preparedness Agency recommends use of both over-the-top ties and frame ties to secure 10-, 12-, and 14-ft.-wide mobile homes. Double units 24 ft. in width are quite stable, and do not require use of over-the-top ties--only frame ties.

Ties are made of wire rope or rust-resistant steel strap which "tie" the mobile home and its steel frame to anchors embedded in the ground. The cable or strap is secured to the anchor with a yoke-type fastener and tensioning device, or with clamps and turnbuckles.

Commercially available ties, consisting of galvanized steel strapping (1 ¼" x .035"), with a minimum breaking strength of more than 4,750 lb., or galvanized steel cable (7/32" 7x7, or ¼" 7 x 19), with a breaking strength of more than 4,800 lb., are acceptable.

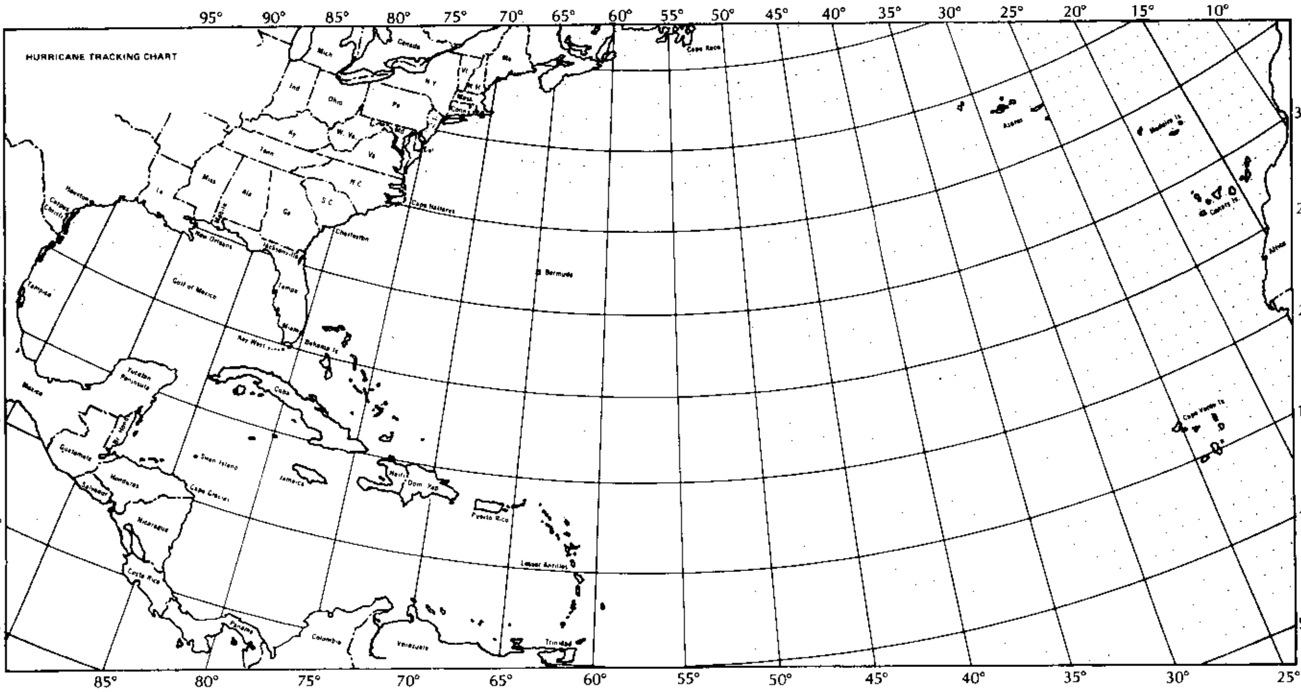
The over-the-top tie is secured to an anchor on each side of the mobile home. Frame ties connect the steel beam supporting the unit to the anchors. Several of each type of tie, with connections and anchors, must be used for an effective tiedown of the whole unit.

Over-the-top ties should be located within 2 feet of each end of the mobile home, and others as needed at intervals between, at stud locations. Commercially available adapters or wood blocks should be used to prevent sharp bends in over-the-top ties, and to keep them from cutting into the unit when tension is applied.

Manufacturers of mobile homes increasingly are including concealed tiedown straps under the skin in new units. The homes are thus more attractive than when exposed tiedowns must be used. The concealed straps still must be secured to ground anchors, and frame ties must also be installed.

Tiedowns should be installed by ALL mobile home owners. If your unit is in a mobile home park and your neighbors don't tie theirs down, other units could be blown into yours in a severe storm.

APPENDIX XIII



Storm Name	Advisory Number	Position						Maximum Wind (mph)	Central Pressure (inches Hg.)	Forward Speed (mph)	Direction	Forecast			
												Movement		Intensity	
		Date	Time (EDT)	Lat. (°N)	Long. (°W)	Miles	from					Forward Speed(mph)	Direction	Increasing	Decreasing

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A. CHECKLIST FOR EVALUATING HOME HURRICANE SAFETY

YES/NO

______ 1. Is your home within 20 miles of the coast?

______ 2. Is your home less than 25 feet above mean sea level?

______ 3. Is your home in an area susceptible to flash floods or river system floods?

______ 4. Do you live in a mobile home within 50 miles of the coast? If your answer is "yes," plan to evacuate your home and proceed to the evaluation checklist.

If you have answered "yes" to any questions above, complete Checklist A. Then proceed to the checklist applicable to your plans for weathering a hurricane--remaining at home or evacuating the area.

YES/NO

______ 5. Is your insurance coverage suitable?

______ 6. Have you stored your valuable papers, jewelry, keepsakes, etc. in a bank vault or secure place that will be safe from storms, fires, or looters?

B. CHECKLIST FOR REMAINING AT HOME DURING A HURRICANE

YES/NO

______ 1. Are you aware that mobile homes are more susceptible to damage by high winds than other types of housing? Your mobile home should be tied at all times. When a hurricane approaches, *leave* for more substantial shelter.

______ 2. If you own a boat, is it moored securely? Do not attempt to ride out a storm on your boat or to return to check its moorings after the storm has arrived. Small boats can be tied close to the house and filled with water to keep them from being blown away.

______ 3. Do you have a full tank of gasoline in your car? Authorities may advise you to evacuate if conditions worsen and your home is no longer safe. If electric power is off, filling stations may not be able to operate pumps for several days.

______ 4. Have you stored or secured outdoor objects that could be blown away or uprooted? Garbage cans, garden tools, awnings, TV antennas, signs, outdoor furniture, and toys can become lethal projectiles in hurricane-force winds.

______ 5. Are windows boarded or shutters in place? (Use good lumber and make sure it is fastened securely. Makeshift boarding or plywood may come apart when wet and do more damage than not having taken any precautions.)

______ 6. Do you have strong bracing for outside doors?

______ 7. Are flashlights and/or emergency lights working? Do you have extra batteries?

______ 8. Do you have a sufficient supply of drinking water on hand? Since city water service may be interrupted, you should sterilize the bathtub, jugs, bottles, pots and pans, then fill them with water. Water in the hot water tank may be used for drinking. A supply of water purification tablets is recommended.

______ 9. Have you stocked non-perishable food that does not need refrigeration and can be eaten without cooking or with little preparation? Remember that electric power may be off and you may be without refrigerator or stove.

______ 10. Do you have sufficient medication and prescription drugs?

______ 11. Do you have a portable radio in working condition so that you can

(continued on reverse side)

C. CHECKLIST FOR EVACUATING THE AREA

If you decide to evacuate, try to leave during the daylight hours well in advance of the storm. Heavy rains and high winds usually precede the storm by six hours.

YES/NO

______ 1. Have you tied down your mobile home?

______ 2. Is a car with a full tank of gasoline ready if needed? Walk to shelter when possible to help alleviate traffic congestion.

______ 3. If you own a boat, is it moored securely? (Do not attempt to ride out a storm on your boat or to return to check its moorings after the storm arrives.) Small boats can be tied next to the house and filled with water to keep them from being blown away.

______ 4. Have you stored or secured outdoor objects that might be blown away? Garbage cans, garden tools, awnings, TV antennas, signs, outdoor furniture, and toys can become lethal projectiles in hurricane-force winds.

______ 5. Are windows boarded or shutters in place? Taping windows helps to reduce flying glass.

______ 6. Do you have strong bracing for outside doors?

______ 7. Have you moved furniture away from exposed windows and doors?

______ 8. Do you have sufficient prescription drugs or medicines?

______ 9. Have you taken only necessary clothing?

______ 10. Have you shut off the main gas valve and pulled the main power switch before leaving?

______ 11. Do you know that downed electric power lines are extremely dangerous?

______ 12. Are you familiar with the best evacuation route to use?

a. Use route______to__________.

b. Use route______to__________.

c. Use route______to__________.

______ 13. If you are marooned, do you know the location and telephone number of your nearest Civil Defense or Red Cross shelters?

a. Address__________Phone____

b. Address__________Phone____

c. Address__________Phone____

(Checklist B continued)

listen to local stations for storm watches and warnings and for instructions from the local EOC?

______ 12. Do you have an axe and wrecking bar immediately available? If the house shifts or falls, these tools may be needed to open doors or to rescue trapped individuals.

______ 13. Have you moved furniture away from exposed windows and doors? Tape windows to reduce the possibility of flying glass.

______ 14. Do you know that it is *extremely* important to stay inside during the storm and not to go out during the lull while the eye is passing?

______ 15. Do you know how to shut off the main gas valve and to pull the main power switch if the house starts to flood? Flooding will extinguish pilot lights and gas may leak. High water can cause shorting of electric lines, which could start fires. It is unlikely that help will be available to control or extinguish fires.

______ 16. Are you aware of the dangers (flying debris) of opening a door or window on the windward side of the house? Exit on the downward side if possible.

______ 17. Are you prepared to evacuate if required? Take only necessary clothing. (It is advisable to have a suitcase packed.)

______ 18. If you have to evacuate at the last minute, do you know which evacuation route to use? Keep up-to-date on the best route by listening to the radio in your area.

a. Use route______to________.

b. Use route______to________.

c. Use route______to________.

______ 19. Do you have the location and telephone number of the nearest Red Cross shelter posted in your house? Information will be given over radio concerning *available* shelters. Remember that the list may not include the shelter closest to your home.

a. Address________Phone____

b. Address________Phone____

c. Address________Phone____

______ 20. Do you know that downed electric power lines are *extremely* dangerous? Do not move or touch them.