HURRICANE

Hazard Description

According to the National Oceanic and Atmospheric Administration (NOAA), a hurricane is an intense tropical weather system of strong thunderstorms with well-defined surface circulation and maximum sustained winds of 74 mph or higher. In the Northern Hemisphere circulation of winds near the Earth's surface is counterclockwise.

A tropical depression intensifies into a tropical storm when maximum sustained winds increase to between 35-64 knots (39 – 73 mph). At these wind speeds the storm becomes more organized and circular in shape and it begins to resemble a hurricane. Tropical storms can be equally problematic without even becoming a hurricane. However, most of the problems a tropical storm causes stem from heavy rainfall, high winds and tidal surge in coastal communities. Incipient hurricane development is evident once barometric pressure (measured in millibars or inches) in the center decreases and winds increase. If atmospheric and oceanic conditions are favorable, the disturbance can intensify into a tropical depression.

When maximum sustained winds reach or exceed 39 mph, the system becomes a tropical storm. It is then given a name, and is closely monitored by the National Hurricane Center in Miami, Florida. In 1979, a six-year rotating list of Atlantic storm names was adopted. The list alternates between male and female hurricane names. Storm names are used to facilitate geographic referencing, for

warning services, for legal issues and to reduce confusion when two or more tropical cyclones occur at the same time. Through a vote of the World Meteorological Organization Region IV Subcommittee, Atlantic cyclone names are "retired," when hurricanes result in substantial damage or death.

Hurricane Wind

Hurricanes are categorized according to the strength of their winds using the Saffir-Simpson Hurricane Scale (See Table 6-2). A Category 1 storm has the lowest wind speeds, while a Category 5 hurricane has the highest. This scale only ranks wind speed, but lower category storms can inflict greater damage than higher category storms depending on where they strike, other weather they interact with, and how slow they move. As a prime example, Hurricane Ike, which struck GBRA in 2008 and is discussed herein, was ranked as a Category 2 storm, yet was one of the costliest natural disasters in Texas history[1].

The ingredients for a hurricane include a pre-existing weather disturbance, warm tropical oceans, moisture, and relatively light winds aloft. Persistent, favorable conditions can produce violent winds, destructive waves, torrential rains, and powerful floods. Annually, an average of ten tropical storms develop over the Atlantic Ocean, Caribbean Sea and the Gulf of Mexico. Many of these storms remain over the water and never impact the U.S. coastline. In an average year, six of these storms become hurricanes. In an average 3-year period, roughly five hurricanes strike the US coastline, killing approximately 50 to 100 people anywhere from Texas to Maine. Of these, two are typically "major" or "intense" hurricanes (a Category 3 or higher storm on the Saffir-Simpson Hurricane Scale).

Table 6-1 profiles the potential winds speeds in miles per hour (MPH) that could be expected in the study area during a hurricane event for various return periods.

Table 6-1. Average Hurricane Wind Speeds by Jurisdiction

JURISDICTION	WIND SPEED (MPH) PER RETURN PERIOD						
	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year	1,000-Year
Caldwell County	**43**	**56**	**71**	**81**	**89**	**100**	**106**
Lockhart	40	53	68	77	86	97	104
Luling	43	56	70	81	89	99	106
Martindale	40	53	67	77	85	95	103
Calhoun County	**64**	**83**	**107**	**121**	**132**	**144**	**152**
Point Comfort	64	83	107	120	130	143	152
Port Lavaca	64	82	105	119	130	142	151
Seadrift	64	83	107	121	132	144	152

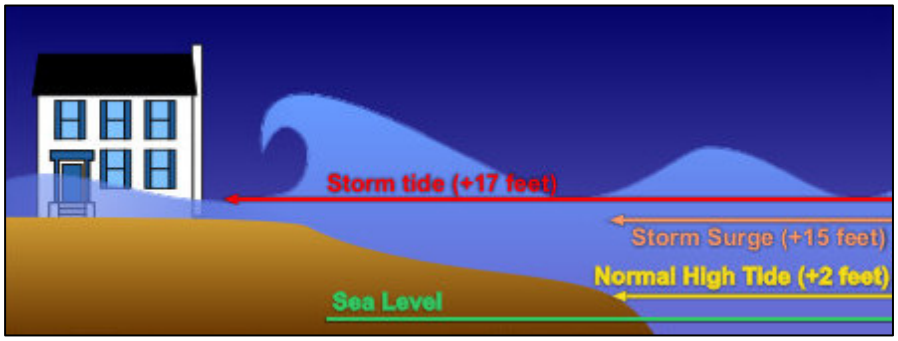
[1] FEMA. 2008. Hurricane Ike Impact Report. Department of Homeland Security, Federal Emergency Management Agency, Mitigation Division. Washington, D.C.

JURISDICTION	WIND SPEED (MPH) PER RETURN PERIOD						
	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year	1,000-Year
DeWitt County	**50**	**65**	**82**	**94**	**103**	**113**	**121**
Cuero	51	66	84	95	105	115	123
Nordheim	49	64	81	93	102	112	120
Yoakum	51	66	83	95	103	114	121
Yorktown	50	65	83	94	104	115	122
Gonzales County	**45**	**59**	**75**	**85**	**94**	**104**	**111**
Gonzales	45	59	74	85	94	104	111
Nixon	44	58	74	84	93	104	110
Waelder	46	60	75	85	95	105	111
Cibolo (Guadalupe County)	38	51	65	75	84	94	101
Kendall County	**30**	**43**	**57**	**67**	**76**	**86**	**94**
Boerne	31	44	59	68	78	87	95
Refugio County	**60**	**78**	**101**	**116**	**127**	**138**	**145**
Austwell	62	80	105	119	130	142	149
Bayside	59	77	100	116	126	137	144
Refugio	59	77	100	115	125	136	144
Woodsboro	59	77	100	116	126	137	144
Victoria County	**58**	**74**	**96**	**108**	**119**	**130**	**138**
Victoria	57	74	95	108	118	130	137

Storm Surge

According to the National Hurricane Center, the greatest potential for loss of life related to a hurricane is from the storm surge. Low pressure and high circular winds “pile” the water into a dome shape that can be 50-100 miles wide. The surge travels with the storm and is most severe on the right side of the storm; relative to the direction the storm travels. Surge can be 15 feet deep, topped by waves and make landfall ahead of the eye. Wind driven waves are superimposed on the storm tide. This rise in water level can cause severe flooding in coastal areas, particularly when the storm tide coincides with normal high tides. Because much of the United States' densely populated Atlantic and Gulf Coast coastlines lie less than 10 feet above mean sea level, the danger from storm tides is tremendous. Figure 6-1 on the following page is a diagram from the National Oceanic and Atmospheric Administration (NOAA) that depicts the possible level of storm surge, compared to sea level and a normal high tide

Figure 6-1. Diagram of Storm Surge (NOAA)



Recently researchers have advocated for the development of another scale for hurricanes specifically geared toward storm surge impact. This new scale would show differences in local bathymetry (the shallow Gulf waters off of Texas enhance storm surge while the deep ocean depths off of southeastern Florida inhibit surge). Although this scale presently does not exist, the NOAA is working to enhance the analysis and prediction of storm surge, as storm surge-induced flooding has killed more people in the United States in hurricanes than all other hurricane-related threats (freshwater flooding, winds and tornadoes) combined since 1900[2].

Location

Although the majority of counties in the GBRA region are located inland from the coast, they are still susceptible to the indirect threats of a hurricane, including high winds and flooding. The coastal counties, which include Refugio and Calhoun, can experience high-force winds, storm surge and flooding due to their location.

The effects of a hurricane begin to diminish as it moves inland; although no single area of the county is free of risk. For example, the winds alone from Hurricane Ike covered 120 miles, stretching across the county, but all areas were impacted by high winds and flooding. Figure 6-2 displays the location of hurricane risk by storm category along the Gulf Coast.

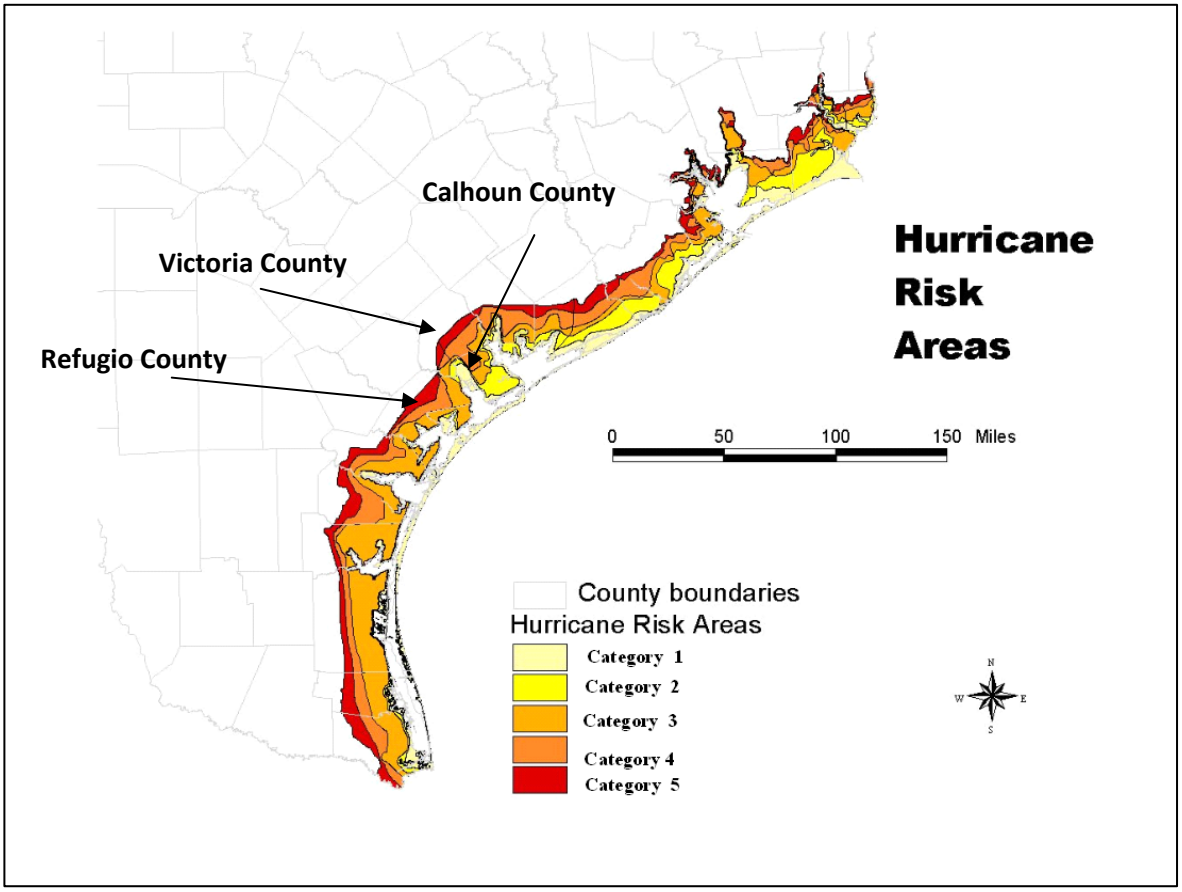
Figures 6-3 and 6-4 depict the coastal flood inundation zones where there is potential for damage to property and loss of life due to storm surge induced high velocity wave action for Calhoun County and Refugio County. Coastal flood inundation zone maps were derived from georeferenced data compiled by the National Weather Service (NWS). Storm surge data was provided from the NWS Sea, Lake and Overland Surges from Hurricanes (SLOSH) data (2009). SLOSH is a modeling tool used to estimate storm surge resulting from historical, hypothetical, or predicted hurricanes.

[2] Source: www.nhc.noaa.gov

SLOSH analysis represents the possible storm surge water level that an area may anticipate for a category of storm. A MOM (Maximum of Maximum) value (a composite measure that expresses the maximum storm surge elevation) for a Category 1 through Category 5 hurricane was used to determine the "surge" or water elevation for a particular area.

For Calhoun and Refugio counties, the Matagorda Bay 2007 (PS2) SLOSH basin was used. In these analyses a shapefile was extracted from the SLOSH Display package. Storm surge inundation areas were then overlaid with census block data, defining the potential maximum surge for coastal locations for each category of hurricane, as well as exposed populations, structures, and critical facilities located in those areas. It should be noted that HAZUS-MH MR4 does not recognize Victoria County as a coastal county. As such, storm surge losses could not be run. However, since the county has a small area of coastline, as illustrated in Figure 6-3, it could be susceptible to storm surge.

Figure 6-2. Hurricane Risk Areas[3]



[3] Source: State of Texas Hazard Mitigation Plan

Figure 6-3. Coastal Flood Inundation Zones in Calhoun County (NWS)

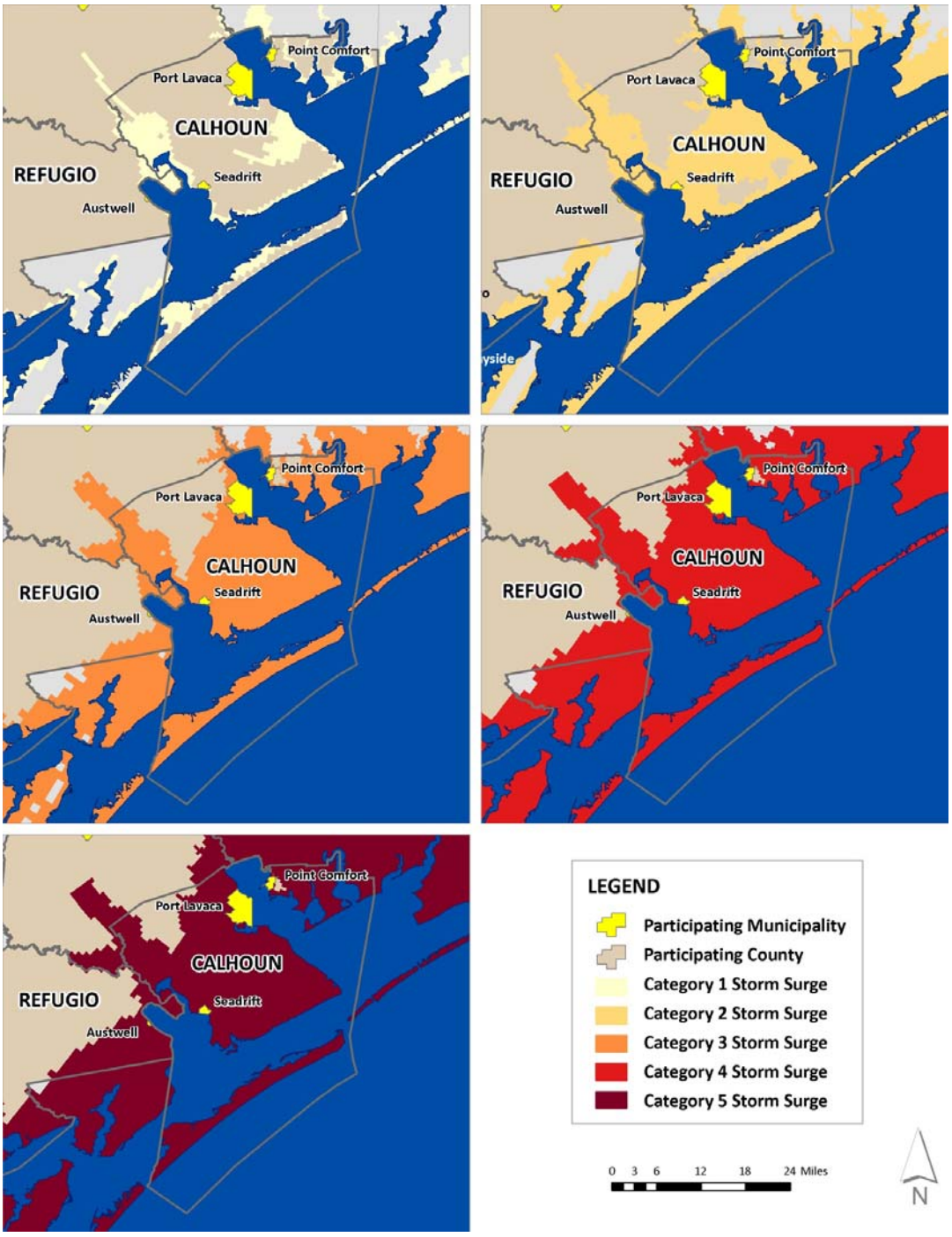
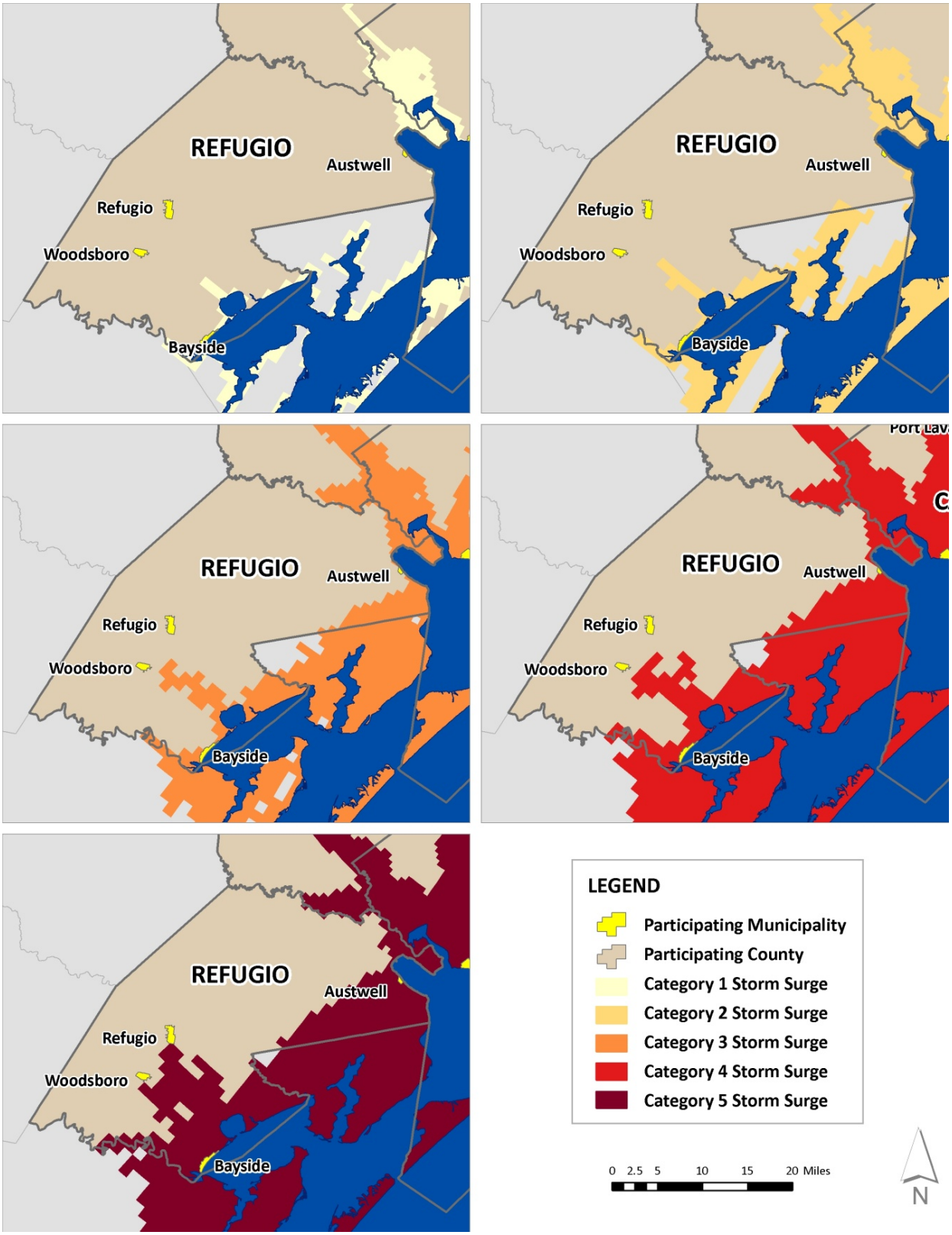


Figure 6-4. Coastal Flood Inundation Zones in Refugio County (NWS)



Extent

The Saffir-Simpson Scale categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential. Wind, pressure, and surge are combined to estimate potential damage. Categories 3, 4 and 5 are classified as "major" hurricanes. Major hurricanes comprise only 20 percent of total tropical cyclone landfalls but they account for over 70 percent of the damage in the United States. Damage from hurricanes can result from spawned tornadoes, coastal flooding from storm surge, and inland flooding from heavy rainfall. Table 6-2 depicts hurricane magnitude and intensity in terms of storm surge and wind speed.

Table 6-2
Saffir-Simpson Scale

CATEGORY	MAXIMUM SUSTAINED WIND SPEED (MPH)	MINIMUM SURFACE PRESSURE (MILLIBARS)	STORM SURGE (FEET)
1	74–95	Greater than 980	3–5
2	96–110	979–965	6–8
3	111–130	964–945	9–12
4	131–155	944–920	13–18
5	155 +	Less than 920	19+

Source: National Hurricane Center

According to NOAA's 2010 Atlantic Hurricane Season Outlook, there is an 85 percent chance of an above normal season. The outlook reflects an expected set of conditions that is very conducive to increased tropical cyclone activity. Most storms form later in hurricane season from August to October.

Historical Occurrences

Hurricane Claudette

Calhoun and Refugio counties were among those impacted by Hurricane Claudette on July 15, 2003. Tropical Storm Claudette entered the Gulf of Mexico on Friday July 12, 2003. Relaxed steering currents produced tropical storm force winds, heavy rains and wave heights up to 15 feet. As early as Sunday July 13th large swells were reaching the sand dunes on Padre Island. Claudette made landfall as a Category 1 hurricane near Port O'Connor, Texas on July 15, 2003. Just prior to landfall storm surge was 5 feet at Port O'Connor in combination with high astronomical tides. Wind speeds ranged from 65-90 mph with gusts to 100 mph.

Claudette produced a brief tornado in Port Lavaca. Damage was not attributed directly to this tornado, rather to the hurricane winds. Claudette continued inland across Victoria, Goliad and Bee counties weakening to a Tropical Storm.

Damages for all of Texas stood at 45.7 million dollars in uninsured losses and 90.0 million in insured losses. These losses do not include crop damage. In the State of Texas two indirect fatalities were also attributed to Claudette and six indirect injuries. Over twenty thousand homes were damaged across the affected area, most of which was classified as minor damage in Victoria County. Over six hundred homes received major damage, again most of which occurred in Victoria County. Over sixty homes were completely destroyed, mostly in Calhoun County. The heaviest rainfall fell across Bee, Goliad and Refugio Counties with four to six inch amounts.

Tropical Storm Erin

Calhoun and Refugio counties were affected by Tropical Storm Erin as it made landfall near Rockport and Lamar, Texas on August 16, 2007. The highest sustained wind speed over land was 21 knots, gusting at 40 knots. Storm tides exceeded two feet and caused minor beach erosion around Seadrift and Port Lavaca. Rainfall ranged from two to four inches across Calhoun, northern Refugio, northern Aransas, Victoria, Goliad, northern Bee and far northern Live Oak counties.

Hurricane Ike

Even though only a Category 2 Storm at landfall, Hurricane Ike, which made landfall in Galveston on September 13, 2008, is ranked as the third most destructive to ever make landfall in the United States.[4] Maximum sustained winds were 100 mph, with hurricane force winds extending outward up to 120 miles from the center and tropical storm force winds extending outward up to 275 miles. Damages are still being estimated but will total in the tens of billions of dollars. Calhoun County experienced heavy winds and rain and a storm surge of four to five feet. The county was designated for Public Assistance by FEMA.

Probability of Future Events

Hurricanes occur in seasonal patterns between June 1 and November 30. Warning time for hurricanes has lengthened due to modern and early warning technology. Based on historical frequency of significant hurricane wind and surge events, the probability of future events to expect is one every 25 years. The probability of such an event in the coastal counties of Calhoun, Refugio and Victoria is unlikely for an annual frequency. However, an event is highly likely on a 25 year frequency.

4 FEMA. 2008. Hurricane Ike Impact Report. Department of Homeland Security, Federal Emergency Management Agency, Mitigation Division. Washington, D.C.

Impact and Vulnerability

The potential severity of hurricane wind impact in the planning area is indicated by the projected loss of function for each jurisdiction. A 100 year hurricane wind is projected to inflict the greatest loss of function of essential facilities to the populated coastal areas of Refugio, Calhoun and Victoria Counties.

Coastal communities are vulnerable to threats directly and indirectly related to hurricane winds, surge and flooding. While the brunt of the storm may remain for those communities on the coast and 150 miles inland, it is possible for the storm to move further inland. A Gulf Coast storm may produce heavy rainfall and cause severe flooding in areas as far north as Ohio. Winds over flat open terrain will take longer to decrease, which can lead to substantial damage as far inland as the Great Plains, the Mid-West or the Eastern Seaboard, depending on the path and interactions with other terrestrial weather systems. Areas of primary impact in the planning area would include coastlines of Calhoun, Refugio and Victoria counties. Low lying coastal areas will flood. Communities along rivers, bays, and estuaries may flood before higher inland areas. Beach front communities will bear the brunt of the strongest hurricane winds. Inland locations in the GBRA Region will be impacted by hurricane winds that may have picked up potentially threatening objects (projectiles).

Hurricane-force winds can easily destroy poorly constructed buildings and mobile homes. Debris such as signs, roofing material, and small items left outside become extremely hazardous in hurricanes. Extensive damage to trees, towers, water and underground utility lines (from uprooted trees), and fallen poles cause considerable civic disruption. In a tropical storm or hurricane, the potential severity of impact is a measure of storm effects such as injuries, critical facility shut down and property damage. Annually, bands of rain from Gulf of Mexico tropical systems will fall in the area. These impacts are limited. Impacts are substantial where the storm makes landfall. When storms make landfall they can have a substantial impact, resulting in fatalities, a complete shutdown of critical facilities, and more than 50 percent of property destroyed or with major damage. Potential losses due to storm surge and hurricane winds are distinct and presented in Tables 6-3 and 6-4.

Table 6-3. Estimated Potential Exposure for Hurricane Storm Surge in Coastal Jurisdictions

JURISDICTION	TOTAL NUMBER OF PEOPLE IN JURISDICTION	NUMBER OF PEOPLE EXPOSED TO SURGE HAZARD	TOTAL VALUE OF ALL BUILDINGS IN JURISDICTION	NUMBER OF BUILDINGS EXPOSED TO STORM SURGE	TOTAL ESTIMATED BUILDING LOSS FROM STORM SURGE
Calhoun County					
Category 1	6,481	3,127	$609,016,000	3,742	$418,250,000
Category 2		4,221		4,504	$489,128,000
Category 3		5,659		5,090	$560,406,000
Category 4		6,480		5,457	$607,975,000

JURISDICTION	TOTAL NUMBER OF PEOPLE IN JURISDICTION	NUMBER OF PEOPLE EXPOSED TO SURGE HAZARD	TOTAL VALUE OF ALL BUILDINGS IN JURISDICTION	NUMBER OF BUILDINGS EXPOSED TO STORM SURGE	TOTAL ESTIMATED BUILDING LOSS FROM STORM SURGE
Category 5		**6,481**		**5,458**	**$608,115,000**
Point Comfort					
Category 1	781	169	$80,897,000	105	$25,650,000
Category 2		169		105	$25,650,000
Category 3		733		434	$76,960,000
Category 4		781		462	$80,897,000
Category 5		781		462	$80,897,000
Port Lavaca					
Category 1	12,035	1,943	$651,340,000	800	$119,146,000
Category 2		3,816		1,709	$227,970,000
Category 3		12,035		5,348	$651,340,000
Category 4		12,035		5,348	$651,340,000
Category 5		12,035		5,348	$651,340,000
Seadrift					
Category 1	1,350	627	$62,036,000	446	$29,882,000
Category 2		1,350		948	$62,036,000
Category 3		1,350		948	$62,036,000
Category 4		1,350		948	$62,036,000
Category 5		1,350		948	$62,036,000
Refugio County					
Category 1	**2,670**	**299**	**$149,487,000**	**156**	**$18,778,000**
Category 2		**376**		**202**	**$22,459,000**
Category 3		**642**		**355**	**$38,076,000**
Category 4		**789**		**439**	**$45,833,000**
Category 5		**1,038**		**578**	**$60,047,000**
Austwell					
Category 1	192	16	$28,397,000	12	$956,000
Category 2		16		12	$956,000
Category 3		16		12	$956,000
Category 4		122		132	24,977,000
Category 5		192		176	$28,397,000
Bayside					
Category 1	360	216	$26,026,000	191	$15,891,000
Category 2		216		191	$15,891,000
Category 3		320		273	$23,461,000
Category 4		360		304	$26,026,000

JURISDICTION	TOTAL NUMBER OF PEOPLE IN JURISDICTION	NUMBER OF PEOPLE EXPOSED TO SURGE HAZARD	TOTAL VALUE OF ALL BUILDINGS IN JURISDICTION	NUMBER OF BUILDINGS EXPOSED TO STORM SURGE	TOTAL ESTIMATED BUILDING LOSS FROM STORM SURGE
Category 5		360		304	$26,026,000
Refugio					
Category 1	2,920	0	$186,843,000	0	$0
Category 2		0		0	$0
Category 3		0		0	$0
Category 4		0		0	$0
Category 5		0		0	$0
Woodsboro					
Category 1	1,683	0	$78,606,000	0	$0
Category 2		0		0	$0
Category 3		0		0	$0
Category 4		0		0	$0
Category 5		0		0	$0

HAZUS-MH wind speed data, inventory and damage functions, and methodology were used to determine the annual expected loss at the county level. Table 6-4 shows annualized property losses and annualized percent loss ratios by jurisdiction, and Table 6-5 shows the expected damage to critical facilities by jurisdiction.

Table 6-4. Potential Annualized Losses by Jurisdiction (Hurricane Wind)

JURISDICTION	TOTAL VALUE OF ALL BUILDINGS IN JURISDICTION	ANNUALIZED LOSS (AL) FOR RESIDENTIAL	ANNUALIZED LOSS (AL) FOR COMMERCIAL	ANNUALIZED LOSS (AL) FOR INDUSTRIAL	TOTAL ANNUALIZED LOSS (AL)	ANNUALIZED LOSS RATIO (ALR)
Caldwell County	**$605,797,000**	**$124,000**	**Negligible**	**Negligible**	**$129,000**	**0.02%**
Lockhart	$618,183,000	$95,000	$7,000	Negligible	$103,000	0.02%
Luling	$264,373,000	$53,000	$6,000	Negligible	$60,000	0.02%
Martindale	$40,522,000	$8,000	Negligible	Negligible	$8,600	0.02%
Calhoun County	**$609,016,000**	**$3,270,000**	**$160,000**	**$244,000**	**$3,674,000**	**0.60%**
Point Comfort	$80,897,000	$289,000	$25,000	$54,000	$368,000	0.45%
Port Lavaca	$651,340,000	$2,329,000	$275,000	$54,000	$2,658,000	0.41%
Seadrift	$62,036,000	$294,000	$21,000	Negligible	$317,000	0.51%
DeWitt County	**$469,085,000**	**$409,000**	**$12,000**	**$12,000**	**$433,000**	**0.09%**
Cuero	$412,893,000	$258,000	$44,000	$9,000	$311,000	0.08%
Nordheim	$25,111,000	$21,000	Negligible	Negligible	$21,900	0.09%

JURISDICTION	TOTAL VALUE OF ALL BUILDINGS IN JURISDICTION	ANNUALIZED LOSS (AL) FOR RESIDENTIAL	ANNUALIZED LOSS (AL) FOR COMMERCIAL	ANNUALIZED LOSS (AL) FOR INDUSTRIAL	TOTAL ANNUALIZED LOSS (AL)	ANNUALIZED LOSS RATIO (ALR)
Yoakum	$370,136,000	$209,000	$32,000	$10,000	$251,000	0.07%
Yorktown	$127,049,000	$103,000	$10,000	Negligible	$116,000	0.09%
Gonzales County	**$457,255,000**	**$191,000**	**$10,000**	**Negligible**	**$204,000**	**0.04%**
Gonzales	$401,785,000	$81,000	$11,000	Negligible	$94,000	0.02%
Nixon	$94,690,000	$30,000	Negligible	Negligible	$32,700	0.03%
Waelder	$37,972,000	$15,000	Negligible	Negligible	$15,400	0.04%
Cibolo (Guadalupe County)	$221,273,000	$46,000	Negligible	Negligible	$51,000	0.02%
Kendall County	**$1,181,519,000**	**$73,000**	**Negligible**	**Negligible**	**$78,000**	**0.01%**
Boerne	$494,789,000	$22,000	Negligible	Negligible	$26,000	0.01%
Refugio County	**$ 149,487,000**	**$674,000**	**$17,000**	**$14,000**	**$705,000**	**0.47%**
Austwell	$28,397,000	$63,000	Negligible	Negligible	$67,000	0.24%
Bayside	$26,026,000	$137,000	Negligible	Negligible	$139,500	0.54%
Refugio	$186,843,000	$546,000	$77,000	$22,000	$645,000	0.35%
Woodsboro	$78,606,000	$365,000	$10,000	Negligible	$379,000	0.48%
Victoria County	**$1,174,737,000**	**$2,956,000**	**$156,000**	**$64,000**	**$3,176,000**	**0.27%**
Victoria	$3,942,383,000	$5,519,000	$791,000	$112,000	$6,422,000	0.16%
TOTALS FOR STUDY AREA[5]	**$12,812,200,000**	**$18,180,000**	**$1,685,800**	**$619,300**	**$20,485,100**	**0.16%**

Table 6-5. Critical Facilities Potentially Damaged by Hurricane Wind

JURISDICTION	TOTAL ESTIMATED NUMBER OF ESSENTIAL FACILITIES	100-YEAR HURRICANE WIND			500-YEAR HURRICANE WIND		
		Loss of Function	Partially Functional	Fully Functional	Loss of Function	Partially Functional	Fully Functional
Caldwell County	**9**	**0**	**0**	**9**	**0**	**0**	**9**
Lockhart	12	0	0	12	0	0	12
Luling	7	2	0	5	7	0	0
Martindale	0	0	0	0	0	0	0
Calhoun County	**3**	**3**	**0**	**0**	**3**	**0**	**0**
Point Comfort	2	2	0	0	2	0	0
Port Lavaca	18	18	0	0	18	0	0

[5] Totals for the study area may include values less than $5,000 for amounts that are classified as "Negligible" in the table.

JURISDICTION	TOTAL ESTIMATED NUMBER OF ESSENTIAL FACILITIES	100-YEAR HURRICANE WIND			500-YEAR HURRICANE WIND		
		Loss of Function	Partially Functional	Fully Functional	Loss of Function	Partially Functional	Fully Functional
Seadrift	3	3	0	0	3	0	0
DeWitt County	**4**	**4**	**0**	**0**	**4**	**0**	**0**
Cuero	12	5	0	7	12	0	0
Nordheim	1	1	0	0	1	0	0
Yoakum	8	3	0	5	8	0	0
Yorktown	4	4	0	0	4	0	0
Gonzales County	**5**	**3**	**0**	**2**	**4**	**0**	**1**
Gonzales	10	3	0	7	10	0	0
Nixon	6	1	0	5	6	0	0
Waelder	2	0	0	2	2	0	0
Cibolo (Guadalupe County)	6	3	0	3	6	0	0
Kendall County	**11**	**0**	**0**	**11**	**0**	**0**	**11**
Boerne	10	0	0	10	0	0	10
Refugio County	**4**	**4**	**0**	**0**	**4**	**0**	**0**
Austwell	0	0	0	0	0	0	0
Bayside	0	0	0	0	0	0	0
Refugio	7	7	0	0	7	0	0
Woodsboro	4	4	0	0	4	0	0
Victoria County	**20**	**20**	**0**	**0**	**20**	**0**	**0**
Victoria	**36**	36	0	0	36	0	0
TOTALS FOR STUDY AREA	**204**	**126**	**0**	**78**	**161**	**0**	**43**

Source: HAZUS-MH