Galveston County Residential Storm Surge Damage Model

User Manual - Final Report April 2014

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Introduction

The Galveston County Residential Storm Surge Damage Model was created by the Severe Storms Prediction, Education, and Evacuation from Disasters (SSPEED) Center with funding from a grant approved by the Texas Land Commissioner pursuant to National Oceanic and Atmospheric Administration Award No. NA12NOS4190164.

The SSPEED Center was established in 2007 with the objective of addressing the threat of severe storms to the Upper Texas Gulf Coast. It is a multi-disciplinary, inter-institutional organization designed to address the following topics:

1. Severe storm forecasting and modeling
2. Real-time flood warning
3. Infrastructure risk modeling and management
4. Evacuation and search-and-rescue modeling and mapping
5. Education and outreach

The SSPEED Center mission is to educate the Upper Texas Gulf Coast region by increasing public awareness of the risks associated with severe storms and hurricanes.

Motivation

In 2008, Hurricane Ike made landfall at Galveston Island. Ike was a strong Category 2 hurricane with maximum winds of 110 mph at landfall. Storm surge was pushed as far as 30 miles inland in parts of eastern Texas and southwestern Louisiana, and in parts of Galveston Bay, storm surge reached heights of nearly 15 feet. Ike caused 23 deaths and left an estimated 2.6 million people without power (Berg, 2009).

Ike resulted in nearly $25 billion in damage, making it the fourth costliest U.S. hurricane exceeded only by Hurricanes Katrina (2005), Sandy (2012), and Andrew (1992). Ike highlighted the vulnerability of the Upper Texas Gulf Coast, and especially the Houston-Galveston Region, to severe flooding from storm surge.

In the wake of the storm, the SSPEED Center assessed a number of probable hurricane landfall scenarios in order to develop a possible worst-case scenario for the Houston Galveston region (Sebastian et al. 2014). The resulting storm surge scenarios indicated that an Ike-sized hurricane making landfall near San Luis Pass and with increased wind speeds of 143 mph at landfall could

produce upwards of 26 feet of surge in Galveston Bay. The results from the study were used in the development of the Galveston County Residential Storm Surge Damage Model.

Developing a Model Framework

Data Collection

Parcel level data was collected from the Galveston County Appraisal District in order to obtain location and total value of residential properties. The residential parcels were isolated from other property types (e.g., commercial, industrial) in the dataset.

Galveston County LiDAR data was obtained from Texas Natural Resources Information System (TNRIS). The dataset resolution was approximately 3m and was used to determine residential structure elevation and, subsequently, depth of inundation from storm surge.

Preliminary Digital Flood Insurance Rate Maps (DFIRMs) were obtained from Mike Fitzgerald, the Floodplain Administrator for Galveston County, in order to determine the locations of residential structures relative to the base flood elevations (BFE) associated with the Special Flood Hazard Area (SFHA), also known as the A Zone, or 100 year floodplain, and the Coastal High Hazard Area, also known as the V Zone.

Modeling of Hurricane Storm Surge

Storm surge was modeled using the coupled Simulating Waves Nearshore (SWAN) model and the ADvanced CIRCulation (ADCIRC) models. The SWAN Model uses a fully implicit finite difference method to compute waves and the ADCIRC Model solves the depth-averaged barotropic form of the shallow water equations for water levels and momentum. The model is operated out of the Institute of Computational Engineering and Sciences at the University of Texas at Austin. More information can be found at adcirc.org.

Four storms were developed for this study – two Category 2 storms and two Category 3 storms. The Category 2 storms were created using the Hurricane Ike wind field and wind speed (110 mph). The Category 3 storms were created using the Hurricane Ike wind field and increasing the wind speeds by 15% to 127 mph. One storm from each category made landfall at San Luis and Galveston Island., respectively. An in depth analysis of the behavior of hurricane storm surge in Galveston Bay can be found in the Journal of Coastal Engineering (Sebastian et al. 2014).

Damage Model Development

The framework for the damage model was created in Geospatial Information Systems (GIS) software. Residential structures were located at the centroid of each parcel, and these locations were used for all subsequent calculations.

Base Flood Elevation (BFE) data was used to calculate the slab elevation above grade of each residential structure, assuming compliance with local building regulations. Preliminary Federal

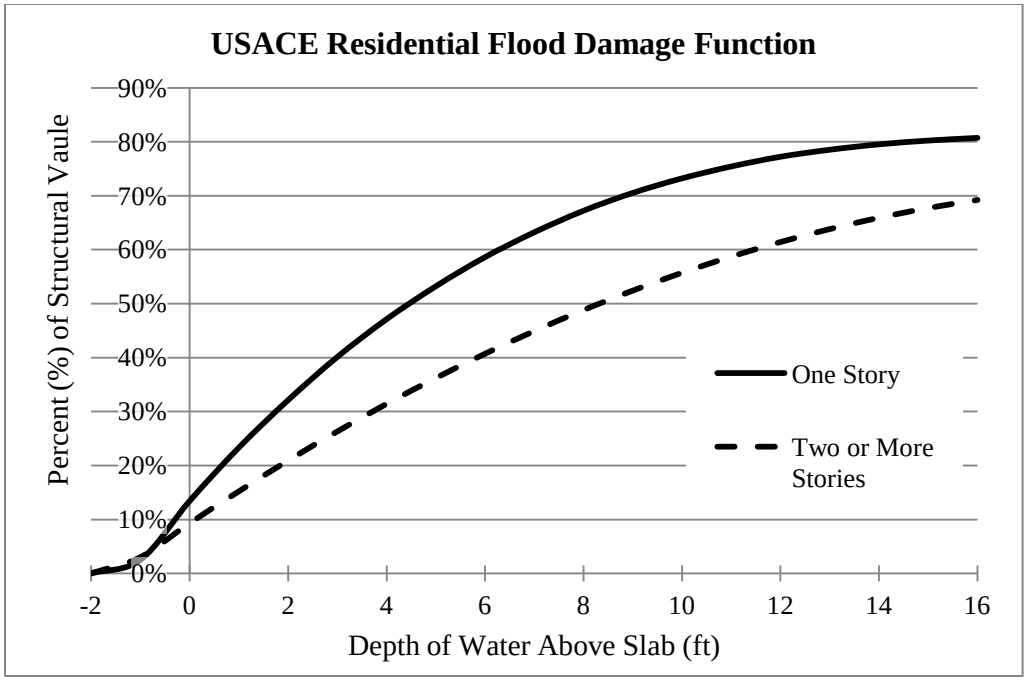
Emergency Management Agency (FEMA) Digital Flood Insurance Rate Maps (DFIRMS) were used to determine the locations where residences were below base flood elevations. The table below displays the required slab displacement from the BFE, as per city or county municipal construction code:

Table 1: Slab elevation above grade as required per city or county municipal code.

City	**Zone A**	**Zone V**
Unincorporated Galveston County	BFE	BFE
Bayou Vista	BFE	BFE
Clear Lake Shores	BFE + 1 ft	BFE + 1 ft
Dickinson	BFE + 2 ft	N/A
Friendswood	BFE + 2 ft	N/A
Galveston	BFE	BFE
Hitchcock	BFE	BFE
Jamaica Beach	BFE	BFE
Kemah	BFE + 1.5 ft	BFE + 1.5 ft
La Marque	BFE	BFE
League City	BFE + 1.5 ft	BFE + 1.5 ft
Santa Fe	BFE + 1 ft	BFE + 1 ft
Texas City	BFE	BFE
Tiki Island	BFE	BFE

The depth of surge at each residence was determined by subtracting the elevation of the slab from the maximum surge elevations. The depth of surge was then correlated to the residential structure value using the Flood Damage Function developed by the Army Corps of Engineers to determine the damage in dollars at each structure. The damage function is shown in Figure 1 below. The damage for each structure was summed over the geographic region, both of the individual cities and the county, for each of the four storm events. A low (one-story) and high (two-story) damage estimate was calculated for each structure.

Figure 1: U.S. Army Corps of Engineers Flood Damage Function for residential structures.



Assumptions & Limitations of the Model

- The location of each residential structure was assumed to be a single point at the centroid of the parcel
- Residential structures were assumed to be 100% compliant with the updated FEMA DFIRMs. (Please note that the currently effective floodplain delineations (FIRMS) are not available in a digital format and thus, were not available for this project.)
- If a structure was not located within the flood zones A or Z, slab elevation was assumed to be at grade.

Results

The results from the ADCIRC+SWAN Model are shown as depth of surge in Galveston County in Figures 2-5 below. Maximum surge heights are also reported at locations of significance, Kemah, Texas City Levee, Jamaica Beach, Galveston Island, and Bolivar Peninsula, for each scenario.

Figure 2: Surge inundation resulting from a Category 2 Storm (110 mph) making landfall near Galveston Island.

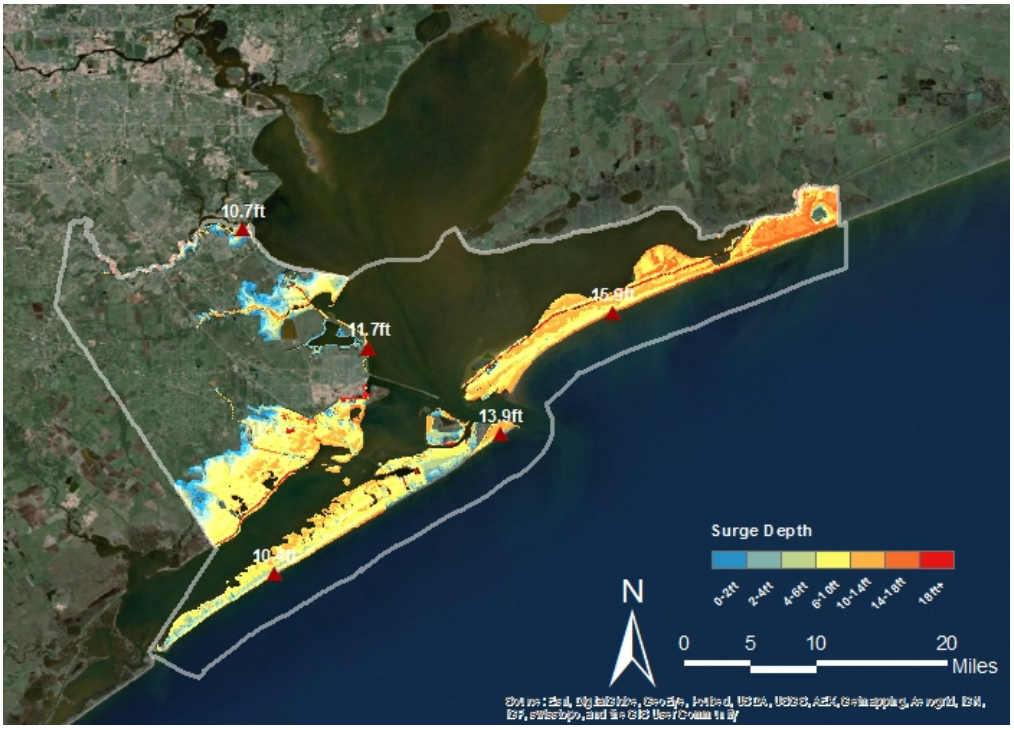


Figure 3: Surge inundation resulting from a Category 2 Storm (110 mph) making landfall near San Luis Pass.

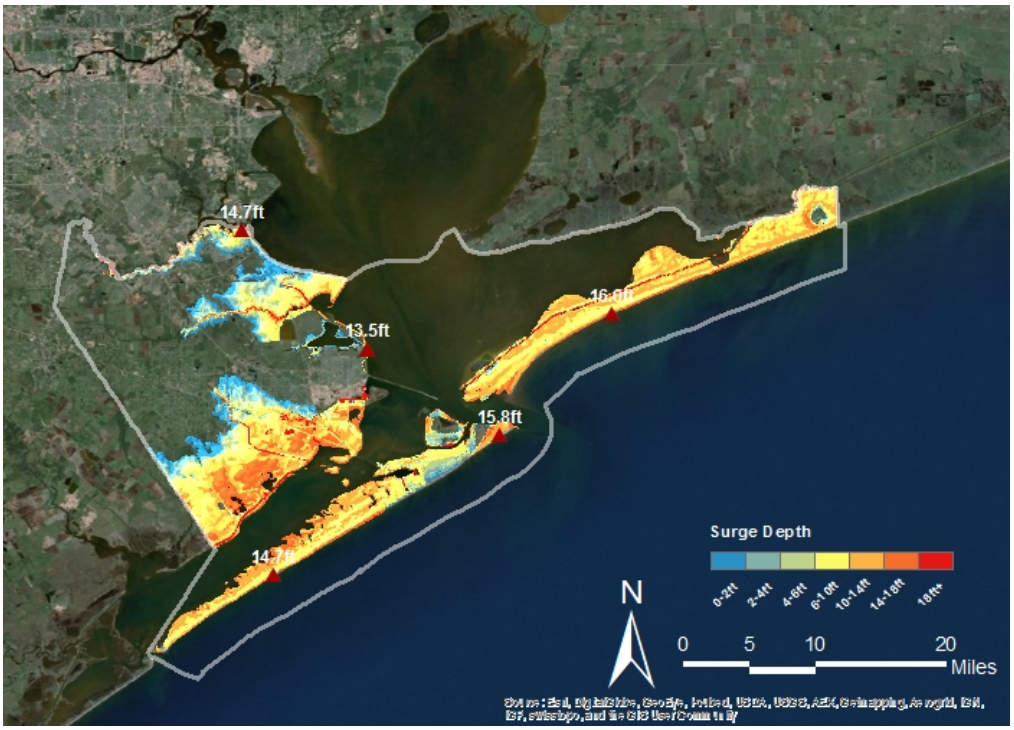


Figure 4: Surge inundation resulting from a Category 3 Storm (127 mph) making landfall near Galveston Island.

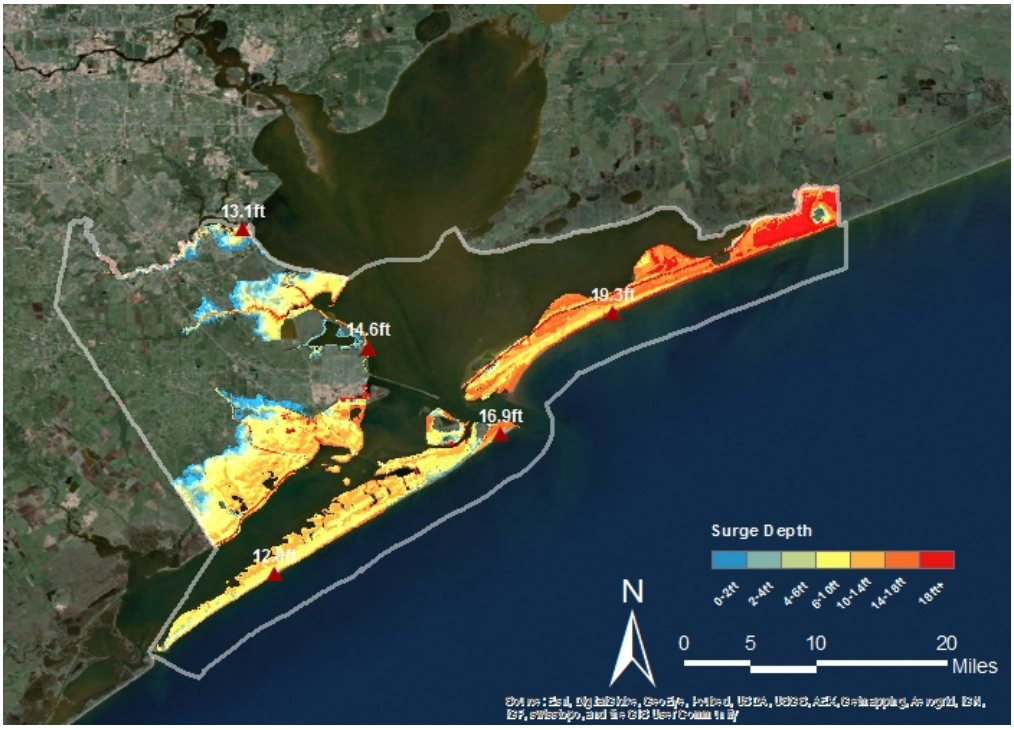
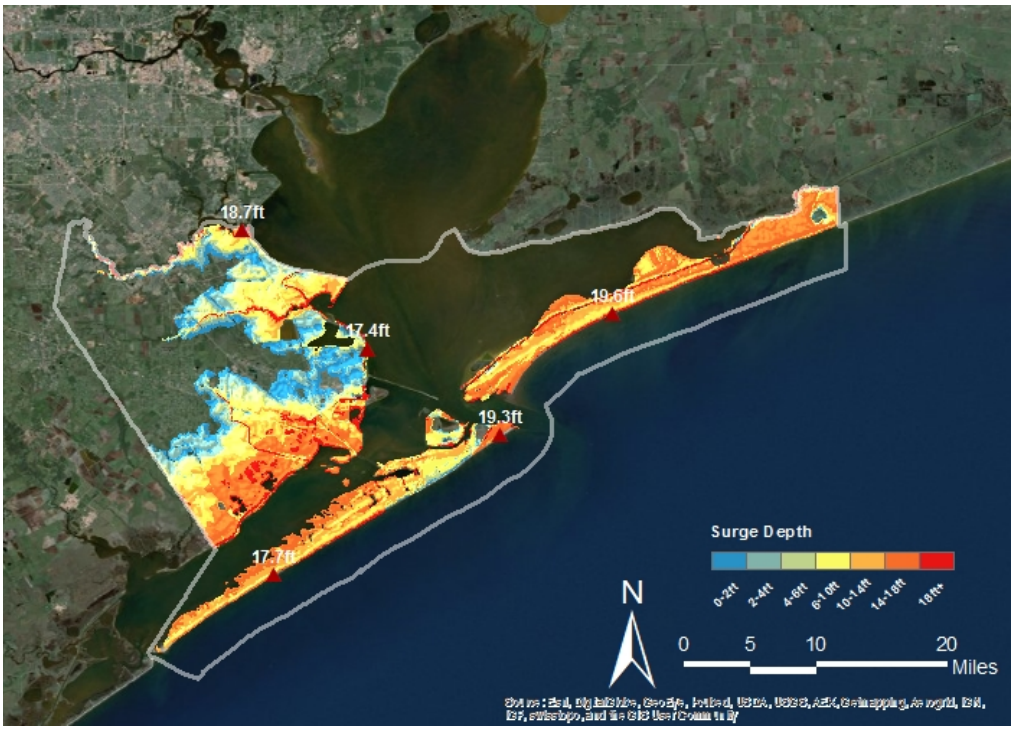


Figure 5: Surge inundation resulting from a Category 3 Storm (127 mph) making landfall near San Luis Pass.



The storm surge inundation mapped in the previous figures resulted in the following damage estimates for individual cities and County of Galveston.

Table 2: Low and high damage estimates for each jurisdiction calculated in millions.

	Category 2 @ Galveston		**Category 2 @ San Luis Pass**		**Category 3 @ Galveston**		**Category 3 @ San Luis Pass**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Bayou Vista	$13.5	$20.0	$34.2	$51.5	$26.4	$40.2	$50.5	$72.3
Clear Lake Shores	$4.10	$5.20	$17.8	$25.7	$10.6	$14.4	$31.5	$44.6
Dickinson	$3.40	$4.80	$32.4	$46.4	$12.4	$16.8	$89.5	$135
Friendswood	$0.50	$0.60	$2.90	$4.00	$1.00	$1.40	$9.20	$12.4
Galveston	$329	$489	$452	$671	$538	$775	$725	$1035
Hitchcock	$3.00	$4.20	$42.5	$63.4	$13.3	$19.7	$61.8	$89.2
Jamaica Beach	$19.1	$28.4	$52.7	$78.7	$37.8	$57.4	$74.4	$106
Kemah	$5.60	$7.90	$22.5	$31.9	$13.0	$18.2	$36.7	$50.5
La Marque	$4.90	$7.30	$27.4	$41.2	$12.2	$18.5	$74.9	$111
League City	$9.50	$13.0	$153	$226	$74.9	$109	$449	$655
Santa Fe	-	-	$0.50	$0.80	-	-	$3.50	$5.30
Texas City	$1.10	$1.70	$2.9	$4.30	$2.30	$3.40	$89.2	$136
Tiki Island	$27.9	$40.9	$52.8	$78.1	$48.2	$71.4	$80.5	$115
Unincorporated	$129	$189	$234	$343	$258	$376	$395	$565
County Total	**$551**	**$812**	**$1,128**	**$1,666**	**$1,048**	**$1,521**	**$2,170**	**$3,132**

The results indicate that storm surge from a strong Category 3 storm making landfall near San Luis Pass could cause as much as $3 billion in damages to residential structures in Galveston County, alone.

Potential Future Work

The purpose of this study was to develop a modeling framework for estimating economic damages from storm surge flooding in Galveston County.

The framework could be extended to include Harris County, as well as other significantly developed coastal counties, allowing us to better assess the economic vulnerability of the Houston-Galveston region. Additional hurricane events can also be added to the study, as they become available. For example, the return-period storms developed by FEMA have not yet been released and until that time, we are unable to truly assess the flood risk associated with a return-period storm.

The model is also limited in that it does not assess the combined risk of storm surge and inland flooding during hurricane events. However, the science is also not yet there. Research at the SSPEED Center related to this topic is on-going, and as new information and modeling techniques become available, the results can also be added to the model framework.

References

Berg, R. (2009). Tropical Cyclone Report Hurricane Ike (AL092008) 1-14 September 2008. National Hurricane Center, 1-41.

Sebastian, A., Proft, J., Dietrich, J.C., Du, W., Bedient, P.B., Dawson, C. (2014). Characterizing hurricane storm surge behavior in Galveston Bay using the Advanced Circulation SWAN + ADCIRC Model. *Journal of Coastal Engineering* 88, 171-181.