Coastal Bend Hurricane Evacuation Study: Vulnerability Analysis Report

Prepared by the

Texas A&M Transportation Institute

and the

Texas A&M Hazard Reduction & Recovery Center

The Texas A&M University System

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Background

This report presents a vulnerability analysis for each of the eight counties in the Coastal Bend Hurricane Study Area (CBHES). This report builds directly on the new or updated hurricane evacuation/risk zones developed by county officials and stakeholders and presented in the *Coastal Bend Hurricane Evacuation Study: Evacuation Zone Development Report.* While that report presents hurricane evacuation/risk zones, focusing on hurricane surge and designating areas of each county subject to inundations from tropical storms through Category 5 hurricanes, this report is an important second step. This report's goal is to answer questions about the population and property—or more generally speaking, the built environment—that is at risk of experiencing some degree of impact due to hurricane surge given its location in one of the risk zones. This kind of analysis should help establish a jurisdiction's vulnerabilities to potential loss of life, damage to the built environment, and potential disruption to services provided by critical facilities if the hazard event actually impacts the area. Ideally, a vulnerability analysis should not only provide information regarding the amount or nature of the population and built environment exposed to hazard risk, but should also help identify properties and populations that are relatively more vulnerable due to the nature of the hazard exposure, as well as the characteristics of the built environment and population. These twin goals will be achieved by:

- Conducting the vulnerability analysis based on the hurricane risk zones themselves.
- Identifying particular parts of the population that may experience greater difficulties responding to potential hurricanes as well as highly vulnerable residential structures.

Figure 1 shows the hurricane evacuation/risk zones developed or updated as part of the Coastal Bend Hurricane Evacuation Study. The highest-risk zone, Zone A, is shaded in reddish pink, Zone B is in orange, and Zone C is in yellow. While not precisely based on the intensity of tropical storms and hurricanes, these zones capture the relative storm surge that risk areas of counties might experience, including relatively low-intensity tropical storms, more minor Category 1 or 2 storms, and major Category 3, 4, and 5 hurricanes. The map also shows that some of the Zone A areas in Nueces and Calhoun Counties range from dark to light reddish pink. The darker zones are even higher-risk areas because of their susceptibility to coastal surge inundations. These counties have chosen to identify some areas in Zone A as even higher-risk areas, which are subject to earlier calls to evacuate. Nueces County has three such areas in Zone A: Zones A1, A2, and A3. Calhoun County has Zone A1, and the remainder of the county is Zone A. Individuals in Zone A locations are much more vulnerable to experiencing impacts due to costal surge for all levels of coastal storms, while those in Zone C are vulnerable to impacts from more major storms.

In addition to some areas being more likely to be impacted by hurricane surge, not all individuals, households, or structures are as resilient or resistant to hurricane impacts as others. Some residential structures, such as mobile homes, are more structurally vulnerable to impacts and therefore cannot be counted on as safe structures to ride out a storm. Similarly, some individuals and households are more socioeconomically or sociodemographically vulnerable than others. Elderly populations, because of health-related and other issues, as well as lower-income households, due to limited economic resources, may experience greater problems and difficulties when trying to prepare for and undertake an evacuation. Because of this variability among residential structures and households, this vulnerability analysis attempts to address elements of both structural and socioeconomic and sociodemographic vulnerabilities by identifying more vulnerable elements of the built environment and population.

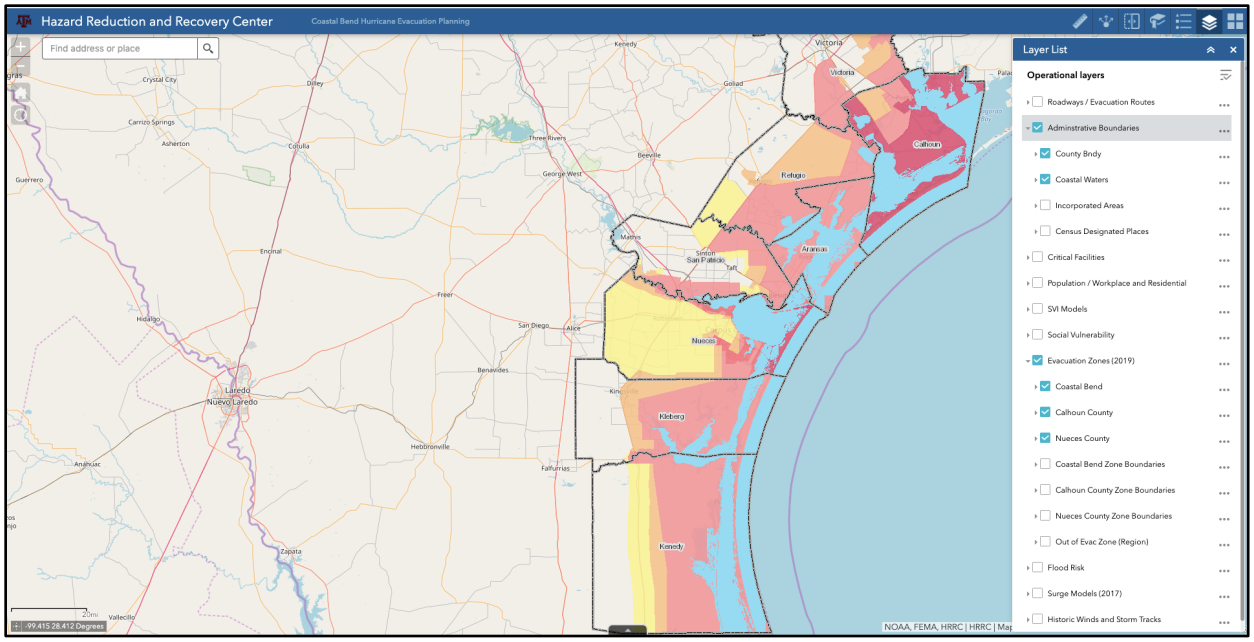

Figure 1. Evacuation Zones for Coastal Bend Counties.

The vulnerability analysis in this report is presented for each county and for each of its hurricane evacuation/risk zones. In other words, the vulnerability analysis will estimate the population, property, and critical facilities that are within each county's evacuation zones from the highest-risk zones (A to C) and in areas outside these zones. In addition, this analysis identifies particular parts or categories of each county's population and different types or elements of the built environment or critical infrastructure to assist each county in its comprehensive evacuation planning activities.

As part of this vulnerability analysis, the project team, comprised of researchers from the Hazard Reduction & Recovery Center (HRRC) and Texas A&M Transportation Institute (TTI) gathered and compiled data from a variety of sources including the respective counties, U.S. Army Corps of Engineers (USACE), Federal Emergency Management Agency (FEMA), State of Texas, U.S. Census Bureau, Esri, and other sources. The team also developed new data and processed existing data, often combining data from multiple sources, to make the information more useful for understanding jurisdictional vulnerabilities. The team has also used data not often employed in vulnerability analyses and developed new data assessment tools that refine and expand the vulnerability assessments for Coastal Bend area counties. In particular, this assessment examines vulnerabilities with respect to employee job and residential locations, highly vulnerable housing (mobile homes, travel trailers, and recreational vehicles [RVs]), and populations that are especially vulnerable to hurricanes because of their social, demographic, and economic characteristics. For example, the project team estimates the average and overall number of vehicles at the disposal of households within each evacuation zone, which is critical for transportation modeling to identify and understanding potential traffic clearance time and congestion problems. This report also presents data on how many households and individuals in each county's evacuation zone ***do not*** have their own vehicles and therefore might need assistance in an evacuation.

Throughout the report, critical data germane to vulnerability assessments and analyses are provided in tabular form for each county by hurricane/evacuation risk zones. These data tables provide the key ingredients for each county to develop and complete its evacuation planning activities. In addition, to

enhance, facilitate, and supplement evacuation planning, the TTI/HRRC team has developed a website that county officials and other interested stakeholders can use in their planning activities. For example, the team has developed high-resolution heat maps, displaying areas likely to have concentrations of vulnerable households, such as households without vehicles, within each evacuation zone. Thus, the project team has estimated the numbers of households that are particularly vulnerable by hurricane risk/evacuation zone, and these results are presented in tabular form in this report and on the website. In addition, the project team developed mapping tools that can be used to identify where these households are likely to be concentrated within each evacuation zone. HRRC hosts these new data and mapping layers by using an internet geographic information system (GIS) platform and a set of tools that users can access using an internet connection and standard web browsers.

In summary, this report contains detailed tables providing vulnerability information for each county, by hurricane risk/evacuation zone. These data are critical for overall evacuation planning by each county. In addition, this report provides information regarding the website, where all of the data presented in this report, many additional data layers, and a complement of mapping tools can be accessed, should the county choose to enhance its evacuation planning activities. The website, its data layers, and mapping tools can also be used to enhance all kinds of planning activities related to resiliency planning, mitigation and recovery planning, and even general planning activities.

Coastal Bend Planning Atlas

The website developed for this project is formally called the ***Coastal Bend Hurricane Evacuation Study (HES) Planning Atlas*** or more simply the Coastal Bend Planning Atlas.[1] The Atlas website data/mapping layers include the new, updated hurricane evacuation/risk zones and the many hazard layers related to surge, wind, and flooding that are discussed more completely in the *Coastal Bend Hurricane Evacuation Zone Development Report*. In addition, there are also data and mapping layers for evacuation routes, critical facilities (emergency medical services [EMS], urgent care, hospitals, fire, police, etc.), built environmental features (hotels, schools, etc.), infrastructure (airports, rail, wind turbines, etc.), and a host of sociodemographic and economic data. These resources can facilitate evacuation and other forms of planning by county and municipal governments, and can be used by other interested stakeholders in Coastal Bend counties.

Throughout this report are example maps taken directly from the Atlas website—discussing the data, showing how the data might be displayed on the website, and offering tips for using the website. For example, Figure 2 shows the same type of content as Figure 1, only the Figure 2 image is at a smaller scale (zoomed in) and has made the evacuation zone layers more transparent so the user can actually see data layers that are underneath. In this case, what is underneath is a base map, displaying cities and road networks. The base map was selected by clicking the *four-box* icon (the red arrow is pointing to this icon) in the upper right-hand corner of the website and then selecting, in this case, *OpenStreetMap* from among the 10 choices available. Base maps include various street maps, two imagery-based maps, terrain or topographical base layers, a National Geographic base map, and a light- or dark-gray minimalist base map.

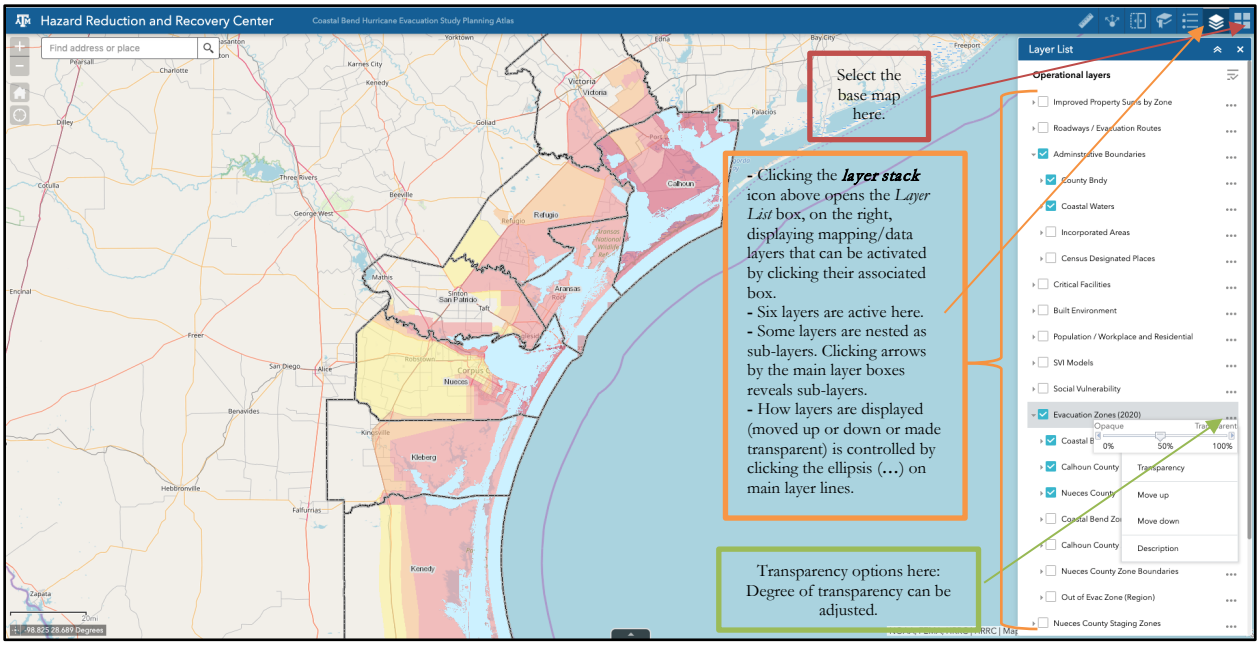

Figure 2. Some of the Coastal Bend HES Website Basics.

[1] The website is at the following location: https://texasatlas.arch.tamu.edu/fv/cb_hes. A link will also be available at the front page of Texas A&M University's HRRC website at http://hrrc.arch.tamu.edu.

To select which data or mapping layers to display, users must click the *stacked layer* icon (the orange arrow is pointing to this icon), which will display the ***Layer List box*** that is displayed on the right in Figure 2. The Layer List box includes the many data layers or groups of layers that can be displayed. Each layer has a solid *greater than symbol* (>) or arrow head and a box associated with it. The *greater than symbol* can be clicked, opening up the layer folder and revealing additional layers that can be activated (or in the case of sub-layers, a legend). In this case, the *greater than symbols* for ***Administrative Boundaries*** and ***Evacuation Zones (2020)*** have been clicked and are now pointing down, revealing the layer options with each category.

To activate and display data layers, the user simply checks the box or boxes associated with each of the layers he or she is interested in displaying. The user needs to be selective in displaying layers; otherwise, one layer will cover up and obscure another layer the user is interested in displaying. In this case for ***Administrative Boundaries***, the check box is selected, but of the four sub-layers, only the *County Boundaries* (the gray county boundaries and county names) and *Coastal Waters* (the light-blue intercoastal water) sub-layers are selected. Similarly, the ***Evacuation Zone (2020)*** check box is selected, but only the evacuation/risk zones for Calhoun, Nueces, and the remainder of the Coastal Bend Counties are selected.[2] If the user only wanted the boundaries for these zones and not full coverage by each color (pink, orange, and yellow), he or she would deselect the zone layers and then select the boundary check boxes only.

The colors for the evacuation zones can also be displayed at 50 percent transparency by selecting the ellipsis (…) to the right of the ***Evacuation Zone (2020)*** layer. As shown in Figure 2, by clicking on the ellipsis (…), the transparency of the layer can be adjusted using the slider. There is also an ordering to the layers being displayed on the map—those layers that are located higher in the Layer List will appear above the other layers further down in the listing on the resulting map. So, the county boundaries and names appear above or over lower layers such as the evacuation zones and can be clearly seen because they are higher in the listing. In this case, the zones' layer is transparent so that roads and cities in the base map are visible beneath the evacuation zone colors. The order of layers can be modified by using the ellipsis (…) to activate options such as shifting the layer up or down in the listing and hence the order in which they are displayed.

[2] Calhoun and Nueces Counties have unique layers because of their higher-risk Zone A designations.

Vulnerability Analysis

The vulnerability analysis examines vulnerabilities for each county in terms of:

1. Population and households.
2. Tourist/seasonal population.
3. Households and populations likely to need transportation assistance.
4. Households and populations residing in mobile homes, travel trailers, and RVs.

Each of these sections presents data that summarize county vulnerabilities with respect to their newly updated hurricane risk/evacuation zones, and also data and mapping layers that are available through the Atlas. The goal here is to create an atlas that will allow local stakeholders to visualize and conduct their own vulnerability assessments as they develop their own local evacuation and disaster plans.

To facilitate this, additional data and analyses are also presented, related to assessments of vulnerabilities for:

5. Critical facilities, features of the built environment, and infrastructure.
6. Employee job and residential locations.
7. Vulnerable property.

Lastly, this report includes a set of tools for conducting additional social vulnerability analyses, whereby concentrations of household, individuals, and housing units with particular vulnerabilities can be mapped to facilitate additional evacuation and disaster planning activities:

8. Social vulnerability mapping layers.

The rest of this report discusses these eight facets of the vulnerability analysis.

1. Population and Household Vulnerability

Hurricane risk/evacuation zones do not correspond to the boundaries of areas defined and employed by the U.S. Census when it undertakes and reports population enumerations as part of the Decennial Census or estimates as part of its American Community Survey (ACS). This makes it difficult to estimate the population located within each evacuation zone in each county. As discussed in the *Evacuation Zone Development Report*, the project team worked with local and state project stakeholders to develop evacuation/risk zones for the Coastal Bend counties that were based on USACE hurricane storm surge risk maps. The actual boundaries of the evacuation/risk zones relied on using identifiable roads—and not the boundaries of census mapping units—to delineate zone boundaries. As a consequence, census units such as census blocks or block groups often do not neatly fit within each of these zones.

Fortunately, USACE was able to make available very high-resolution *Landscan* data for this project. These data, developed by Oak Ridge National Laboratory, estimate the numbers of individuals in very small grid cells (circa 2018). These small grids can be more easily associated with evacuation zone areas than can census block data, particularly for areas with less population density. Therefore, the project team could more accurately distribute the estimates of population locations for Coastal Bend counties into and outside their respective hurricane evacuations/risk zones.

Table 1 presents population estimates for the numbers of individuals and households (HH) located in each of the evacuation zones for each of the eight counties in the Coastal Bend Study Area. The *Landscan* data include estimates for both daytime and nighttime populations. Since the focus here is on evacuation, and evacuations are usually undertaken by households from their residences and not workplaces, all estimates are based on nighttime population estimates. The *Landscan* data estimate the numbers of individuals, so to convert these individual estimates for each zone into household estimates, the project team simply divided the total number of individuals in each zone by the average household size for each county obtained from the U.S. Census. In addition, the project team calculated the numbers of vehicles across all households within each county and county evacuation/risk zones. For the purpose of these estimates, the project team employed the average number of vehicles per household for each county. Both the average household size and number of vehicles per household were derived or obtained from the ACS 5-year estimates for 2017.[3]

Given the variable numbers of evacuation zones, Table 1 has been broken into four panels:

- The northernmost counties, Calhoun County and Victoria County.
- The middle counties, Aransas County, Refugio County, and San Patricio County.
- The southernmost counties, Kenedy County and Kleberg County.
- Nueces County, which has the most evacuation/risk zones.

[3] The average household size and number of vehicles, respectively, by county are as follows: Calhoun: 2.79 and 1.917, Victoria: 2.75 and 1.831, Aransas: 2.56 and 1.807, Refugio: 2.64 and 1.718, San Patricio: 2.84 and 1.816, Kenedy: 3.68 and 1.191, Kleberg: 2.70 and 1.710, and Nueces: 2.72 and 1.760.

Table 1. Estimated Population, Households, and Vehicles by Evacuation/Risk Zone (circa 2018).

County		Zone A1	Zone A	Zone B	Zone Totals	County Totals
Calhoun	Estimate	15,640	5,989	115	21,744	21,744
	% of Co. pop.	71.9%	27.5%	0.5%	100.0%	
	Est. HHs	5,615	2,150	41	7,807	7,807
	Est. vehicles	10,764	4,122	79	14,965	14,965
Victoria	Estimate	n/a	620	2,047	2,667	92,084
	% of Co. pop.		0.7%	2.2%	2.9%	
	Est. HHs		225	743	968	33,433
	Est. vehicles		412	1,361	1,773	61,215

		Zone A	Zone B	Zone C	Zone Totals	County Totals
Aransas	Estimate	25,572	n/a	n/a	25,572	25,572
	% of Co. pop.	100.0%			100.0%	
	Est. HHs	9,990			9,990	9,990
	Est. vehicles	18,052			18,052	18,052
Refugio	Estimate	3,522	1,349	14	4,885	7,224
	% of Co. pop.	48.8%	18.7%	0.2%	67.6%	
	Est. HHs	1,333	511	5	1,849	2,735
	Est. vehicles	2,291	877	9	3,177	4,699
San Patricio	Estimate	24,854	2,464	13,683	41,001	67,219
	% of Co. pop.	37.0%	3.7%	20.4%	61.0%	
	Est. HHs	8,742	867	4,813	14,422	23,644
	Est. vehicles	15,876	1,574	8,740	26,190	42,938

		Zone A	Zone B	Zone C	Zone Totals	County Totals
Kenedy	Estimate	65	6	294	365	417
	% of Co. pop.	15.6%	1.4%	70.5%	87.5%	
	Est. HHs	18	2	80	99	113
	Est. vehicles	21	2	95	118	135
Kleberg	Estimate	697	12,789	n/a	13,486	31,088
	% of Co. pop.	2.2%	41.1%		43.4%	
	Est. HHs	258	4,740		4,998	11,522
	Est. vehicles	442	8,105		8,547	19,702

		Zone A1	Zone A2	Zone A3	Zone B	Zone C	Zone Totals	County Totals
Nueces	Estimate	12,942	59,968	40,821	70,074	177,412	361,217	361,217
	% of Co. pop.	3.6%	16.6%	11.3%	19.4%	49.1%	100.0%	
	Est. HHs	4,758	22,047	15,008	25,763	65,226	132,802	132,802
	Est. vehicles	8,374	38,803	26,414	45,342	114,797	233,731	233,731

As is evident from the last columns in each panel, population size varies widely among the counties in the Coastal Bend, with Nueces County at one extreme with a population well over 350,000 and Kenedy County at the other extreme with a population less than 500. There are also considerable differences in not only the size of each county's population located in evacuation/risk zones, but also in the relative size of these populations compared to a county's total population.

The two northernmost counties, Calhoun and Victory Counties, reflect these extremes in variability not only in the numbers of individuals and households located in evacuation/risk zones, but also in terms of the relative percentages of their populations vulnerable to hurricane surge risk. Calhoun County's population (21,744) is highly vulnerable to hurricane storm surge. Nearly 72 percent of its population falls into its highest-risk zone, Zone A1, with the majority of the remaining population (27.5 percent) falling into the remainder of Zone A. The final 0.5 percent falls into Zone B. Calhoun County has an estimated 15,000 vehicles; the vast majority of nearly 11,000 are associated with households in its highest-risk zone (Zone A1), just over 4,000 are associated with households in the remainder of Zone A, and just over 75 are associated with households in Zone B. Victoria County's two evacuation/risk zones, A and B, fortunately hold relatively few people. Specifically, under 3,000 individuals (or about 3 percent of the county's total population) are located in Zone A (0.7 percent) and Zone B (2.2 percent). These individuals are spread over an estimated 968 households, which are estimated to have just under 1,800 vehicles that might be employed in evacuations.

The three counties in the middle of the Coastal Bend—Aransas, Refugio, and San Patricio—also vary considerably in their population sizes, with San Patricio County having the largest population of just over 67,000, Aransas County just under 25,600, and Refugio County just over 7,000. All of these counties have substantial percentages or all of their populations at risk for hurricane storm surge.

Aransas County's population falls completely in Zone A—in other words, 100 percent of its population is at very high risk. Just over 18,000 vehicles are estimated to be associated with the 100 percent of Aransas County's households that will be involved in an evacuation.

Just under 68 percent of Refugio County's population is located in one of its three hurricane risk/evacuation zones. Specifically, nearly 49 percent (3,522) are in Zone A, just under 19 percent (1,349) are in Zone B, and 0.2 percent (14) are in Zone C. Together, these individuals make up 1,849 households with an estimated 3,177 vehicles among them.

Nearly 37 percent (25,000) of San Patricio County's population is located in Zone A, with an additional 3.7 percent (2,464) in Zone B, and just over 20 percent (13,683) in Zone C. In total, 61 percent of San Patricio County's population (just over 41,000 individuals) in 14,400 households is located in a hurricane evacuation/risk zone. Nearly 16,000 vehicles are associated with Zone A households, just over 1,500 vehicles are associated with Zone B households, and nearly 9,000 vehicles are associated with Zone C households in San Patricio County.

Kenedy and Kleberg Counties are the two southernmost counties in the study area. Kleberg County has the larger population of the two, but Kenedy County has a larger percentage of its population located in evacuation zones. Kleberg County has only 2 percent (697 individuals) of its population in Zone A but just over 41 percent (12,789 individuals) of its population in Zone B. Together, just over 8,500 vehicles are associated with these households. For Kenedy County, nearly 16 percent (65 individuals) of its population is in Zone A, 1.4 percent is in Zone B, and 70.5 percent (294 individuals)

is in Zone C. An estimated 118 vehicles are associated with households in the three evacuation zones in Kenedy County.

Nueces County has by far the largest population of the counties in the study area. Given its vulnerability to surge, population size, and geography, county stakeholders have designated more hurricane evacuation/risk zones associated with Zone A to facilitate a staged evacuation process. Staging the evacuation of Zone A into three parts provides the opportunity for households in the highest-risk zone, Zone A1, to evacuate first, followed by Zone A2 and then Zone A3. This staging process should generate fewer bottlenecks and delays, resulting in a safer evacuation. Zone A1 comprises the barrier island, which has 3.6 percent of the county's population (nearly 13,000 individuals) in just over 4,750 households with nearly 8,500 vehicles. Zone A2 contains nearly 17 percent of the county's population (nearly 60,000 individuals) in just over 22,000 households with nearly 39,000 vehicles. Finally, Zone A3 adds just over 11 percent of the county's population (almost 41,000 people) in 15,000 households with around 26,400 vehicles. Combined, the three Zone A areas include 31.5 percent of the county's population (just under 114,000 individuals) and approximately 73,600 vehicles. Clearly, a staging process makes sense, given these population sizes and the geography of the area.

Nueces County's Zone B includes 19.4 percent of the county's population (over 70,000 individuals) in 25,800 households with over 45,000 vehicles. And finally, Nueces County Zone C[4] includes the remaining 49.1 percent of the county's population (just over 177,000 individuals) in 65,200 households with nearly 115,000 vehicles.

The data associated with the numbers of individuals, households, vehicles, and much of the additional data discussed in following sections are available instantly using the Coastal Bend Hurricane Evacuation Study Planning Atlas by simply left-clicking on a county's evacuation zone. Figure 3 shows how to obtain these details.

[4] Nueces County officials elected to designate the remainder of Nueces County as Zone C due to anticipated extended durations for losses of critical services due to extremely powerful hurricanes, even though much of Zone C is outside areas susceptible to Category 5 hurricane storm surge inundation.

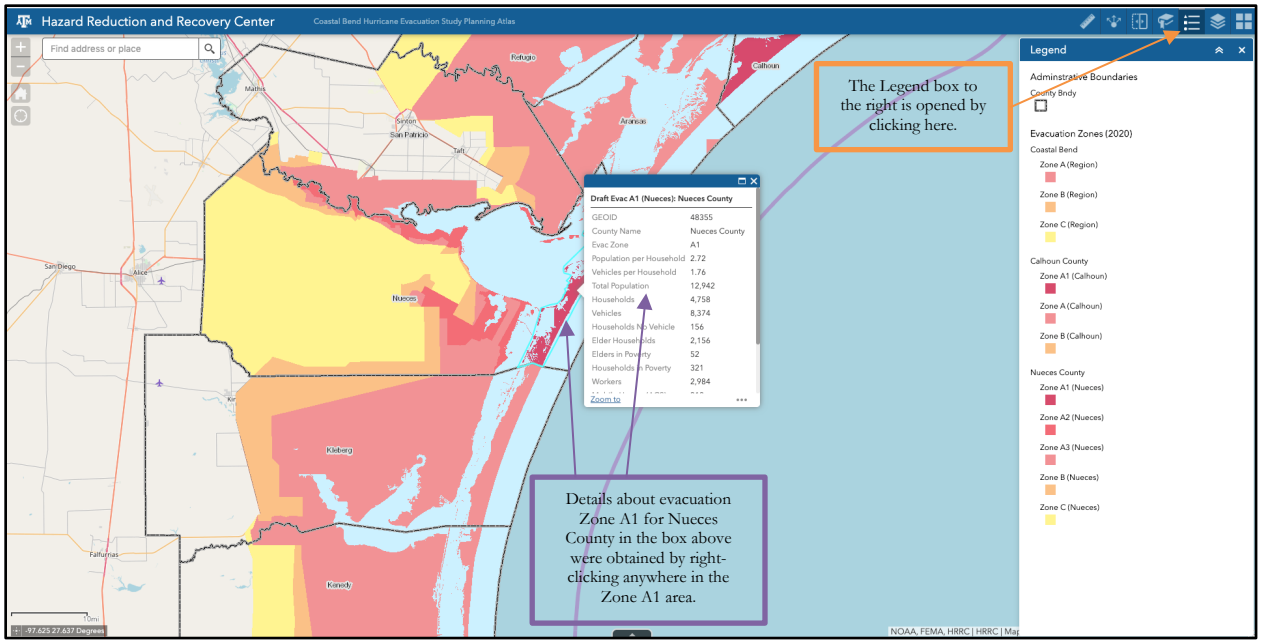

Figure 3. Example for Obtaining Vulnerability Data for Evacuation Zone A1 in Nueces County.

2. Estimates of Tourist/Seasonal Population

The project team gathered and compiled various sources of data to generate estimates for the total tourist/seasonal population that may be in the area and therefore will need to be evacuated, or at least accounted for in the evacuation process. Ideally, local officials should ask these populations to leave prior to mandatory evacuations being ordered for the long-term, residential population. Indeed, a critical part of the county and municipality evacuation planning efforts should involve working with hotels, seasonal property renters, RV parks, campgrounds, etc.

Given the limited level of knowledge of the area and routing that the tourist population is likely to have, trying to ensure these populations are out far ahead of the evacuation of residents should be a priority. To achieve this goal, strong communication and coordination will be necessary between emergency management, local political leaders, and the owners and managers of hotels, seasonal rental properties, camping facilities, and RV/trailer parks. In light of potential liability issues, businesses and individuals renting to these populations are often willing to work with local authorities to help ensure compliance.[5]

Attempting to estimate seasonal/tourist population is important, because the goal is of course getting these individuals moving, into their vehicles, and out of the area as early in the process as possible, before residents of the area also enter the roadway system. The potential convergence of seasonal and residential traffic entering the roadway system at the same times could lead to major problems. Hence, for evacuation reasons, the focus is less on estimating the size of this population, and more on estimating the number of vehicles associated with this population that must enter and pass through the evacuation road network. The primary data needs were information on the number of hotels and motels in the area, along with their capacities, and the numbers of seasonal dwelling units not associated with hotels that might be rented out to tourist/seasonal populations.

The primary data for this task were acquired from the Texas Comptroller of Public Accounts, which has data on hotels/motels and, more often than not, their capacities (number of rooms). Interestingly, these data also included some information on RV parks and camping facilities. While it was generally assumed that the data from the Texas Comptroller were the most accurate, they were supplemented with data on hotels from FEMA Region IV. Most importantly, these data were then cleaned, edited, modified and supplemented by data obtained from Google, Google Maps, and Google Imagery Web Map Services for Texas along with data from the U.S. Census on seasonal rental units.

At its maximum, the data included information on over 3,250 possible seasonal rentals, hotels, and RV/camping locations. These data were then geo-coded/referenced, and duplicates were removed.[6] Unfortunately, less than 20 percent were able to be geo-referenced based on their address. Data that were not properly geo-located were geo-referenced by hand using initial locations based on address points, street segments, and zip codes. Key to this process was employing Google, Google Maps, and Google Imagery Web Map Services. Additionally, the Google-based data were employed to find additional facilities that were missing from the Texas Comptroller data and other sources.

[5] Compliance could be increased by offering incentives (refunds for unused rental time) or simply closing facilities by management.

[6] In many cases, businesses that paid their taxes in multiple payments (i.e., quarterly) appeared to be duplicated in the Texas Comptroller's data set.

In the final analysis, the data set contains information on over 2,243 seasonal/vacation units, hotels, motels, and various forms of RV/camping locations. This included 2,156 that came primarily from the initial Texas Comptroller data and an addition 87 identified by using other Google-based services. These data sources were converted into GIS layers and are available on the Coastal Bend Hurricane Evaluation Study *Planning Atlas* website.

Figure 4 displays an example of the hotel layers for parts of Nueces, San Patricio, and Aransas Counties and also employs one of the imagery base maps upon which data can be displayed. For simplicity sake, the GIS layer identifies seasonal rentals (locations with fewer than five units), somewhat larger numbers of units (five to 10), and larger-capacity facilities (11 or more—sometimes many more units). For the estimation process, the project team wanted to err on the side of safety, particularly for traffic modeling purposes, so full occupancy was assumed. Additionally, for estimation purposes, the project team assumed that each hotel unit would have two vehicles associated with its occupied units, while seasonal units were assumed to have 2.5 vehicles. The assumption here was that facilities with a smaller number of units are often single-family residences that are rented or leased to vacationers; therefore, they would in general have more people occupying the unit and therefore more vehicles.

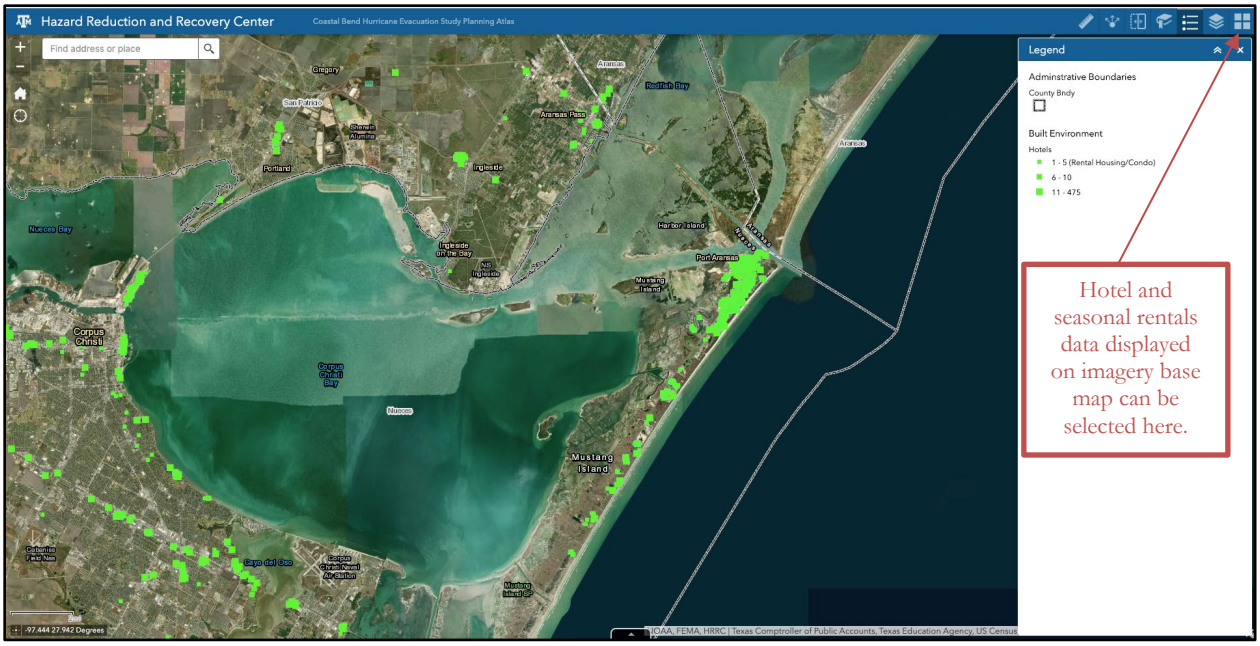

Figure 4. Hotels and Seasonal Units in Nueces, San Patricio, and Aransas Counties.

Table 2 presents the data on estimated hotel/motel and seasonal rental units located in each evacuation zone for each of the Coastal Bend counties that had such facilities. Not surprisingly given that these facilities are generally employed by visitors coming to be near the Gulf of Mexico, in total, 99.6 percent of the smaller seasonal rentals and 92.1 percent of the larger hotels/motels are located in the hurricane evacuation zones of Coastal Bend counties. In Aransas County, since the entire county is in Zone A, all of its seasonal and hotel/motel units are in evacuation Zone A. These units could potentially add an additional 6,300 or nearly a 35 percent increase in the numbers of vehicles evacuating. In San Patricio County, over 3,000 additional vehicles could potentially be evacuating, representing just over an 8 percent increase in evacuating vehicles.

Table 2. Estimated Hotel/Motel and Seasonal Units and Vehicles for Coastal Bend Counties by Evacuation Zones.

	Seasonal units (<5)			*Hotel/Motel units (≥5)*			
County	Count of locations	Rooms capacity	# of vehicles *(2.5 veh. per unit)*	Count of locations	Rooms capacity	# of vehicles *(2 veh. per unit)*	Total estimate # of vehicles
Aransas	**411**	**591**	**1,478**	**75**	**2,411**	**4,822**	**6,300**
A	411	591	1,478	75	2,411	4,822	6,300
Calhoun	**97**	**130**	**325**	**38**	**945**	**1,890**	**2,215**
A	-	-	-	4	110	220	220
A1	97	130	325	34	835	1,670	1,995
Kleberg	**17**	**35**	**88**	**17**	**935**	**1,870**	**1,958**
A	14	28	70	2	14	28	98
B	3	7	18	14	892	1,784	1,802
Out	-	-	-	1	29	58	58
Nueces	**1,131**	**1,602**	**4,005**	**364**	**19,202**	**38,404**	**42,409**
A1	1,072	1,513	3,783	224	5,013	10,026	13,809
A2	37	50	125	51	6,458	12,916	13,041
A3	2	7	18	15	2,057	4,114	4,132
B	5	6	15	14	1,216	2,432	2,447
C	15	26	65	60	4,458	8,916	8,981
Refugio	-	-	-	**7**	**143**	**286**	**286**
A	-	-	-	1	10	20	20
B	-	-	-	2	61	122	122
Out	-	-	-	4	72	144	144
San Patricio	**9**	**10**	**25**	**39**	**2,018**	**4,036**	**4,061**
A	8	8	20	22	985	1,970	1,990
B	1	2	5	1	62	124	129
C	-	-	-	8	680	1,360	1,360
Out	-	-	-	8	291	582	582
Victoria	**6**	**12**	**30**	**32**	**2,329**	**4,658**	**4,688**
Out	6	12	30	32	2,329	4,658	4,688
Grand Total	**1,671**	**2,380**	**5,950**	**572**	**27,983**	**55,966**	**61,916**

By far, the most sobering numbers are associated with Nueces County. If evacuations were called for all Zone A areas (A1, A2, and A3), nearly 31,000 more vehicles could be added to the number of vehicles being used by local residents in the evacuation. This represents a 42 percent increase in potential vehicles evacuating, many of which are being driven by individuals unfamiliar with the area and evacuation process. Indeed, just focusing on the highest-risk zone—A1—represents an addition of nearly 14,000 vehicles, representing a 165 percent increase in vehicles entering the evacuation stream in addition to the permanent residents in that zone. Clearly, getting the vacation/seasonal population off the barrier island long before the local residents must evacuate will be critical.

3. Populations Needing Transportation Assistance

Many will remember seeing images of the devastating consequences of Hurricane Katrina. Primary among these images were the many individuals stranded on their rooftops hoping to be rescued in the aftermath of Katrina and subsequent flooding of New Orleans due to levee failures. One of the leaders from Texas Task Force 1 relating the Katrina efforts mentioned a rescue of an elderly African-American woman and her tearful apology to them for having to rescue her; she also said that she could not evacuate because she did not have a car. This leader noted that all of the people rescued were not only thankful but also apologetic, with far too many noting that they had no way or ability to evacuate themselves. Juxtaposing these images, along with the horrors of those that lost their lives, with the images of the rows of yellow school buses stranded in flood waters that were allegedly to be used to help in the evacuation process is sobering.

In the United States, it is generally assumed, and for the most part it holds, that households will evacuate themselves employing their own or household vehicles (Lindell et al., 2019; Maghelal, Li, and Peacock, 2017; Maghelal, Peacock, and Li, 2017). There is also evidence that some households without vehicles will obtain rides from non-household family members, other relatives, or friends (Wu, Lindell, and Prater, 2012; Lindell et al., 2011; Peacock et al., 2007. Furthermore, households may borrow vehicles from friends or non-household family members as well as rent vehicles during an evacuation. And yet there is clear evidence that these sources are not always available, and in some areas, particularly highly dense urban environments, large parts of a population are dependent on public transportation.

As Lindell et al. (2019) have noted, the question of the role governmental agencies should play helping evacuate is still an open one, but it is equally clear that some jurisdictions recognize that many individuals and households will have problems during evacuations because they simply do not have access to their own vehicles or other forms of transportation. Consequently, some jurisdictions have responded by developing contingency plans designating centralized pickup areas where individuals/households can gather for transportation on buses to safe areas or shelters. Some communities have also promoted or developed registries, particularly for elderly populations, that might need assistance during an evacuation. Still others have worked with volunteer organizations and churches to develop plans for addressing the special transportation and other needs during an evacuation. Of course, the first step in this process is trying to understand the nature of the potential problem that jurisdictions might face with populations that potentially need transportation assistance.

There is no definitive approach for determining the precise size of the populations likely to need assistance, much less the specific locations of the individuals or households making up this population. Therefore, a variety of approaches to potentially capture the nature, size, and estimated locations for populations needing assistance can be taken. One obvious way of estimating the numbers of households or individuals needing assistance is to obtain estimates of households that do not have personal or private vehicles that can be used in evacuation. As noted previously, it is generally assumed that households will evacuate themselves using their own vehicles. Therefore, knowing the numbers and potential locations for concentrations of households without their own vehicles is a reasonable first step.

Next, drawing from the evacuation research literature, particular types of households or individuals that are likely to experience problems and issues in evacuations can be identified. The assumption here is that these households, even if they have access to a vehicle, may not in fact have access to a reliable

or even working vehicle at the time of an evacuation, may lack the financial resources to fuel their vehicle or afford the additional expenses associated with an evacuation, or may simply not have the capacity to operate their own vehicle or be able to pull things together in time to evacuate. For example, research has shown that the elderly, particularly elderly households and lower-income households, often fail to evacuate or leave much later, when conditions are more dangerous. Research has found that census block groups (quite similar in size to neighborhoods in urban areas) with high concentrations of elderly households and households in poverty were also areas with higher concentrations of households that were less likely to evacuate for Hurricane Ike and, if they did evacuate, were on average later in the evacuation process (Van Zandt et al., 2012; Peacock et al., 2012). In light of these findings, this report presents statistical tables of the numbers of households without a vehicle and elderly households by evacuation zones for each county. Additionally, mapping tools are available in the Coastal Bend HES *Planning Atlas* that can be used to display areas with higher concentrations of households without vehicles and the elderly throughout the area.

Table 3 presents ACS 5-year data for 2013–2017 on the number of households by hurricane evacuation/risk zone for each county that ***do not*** have their own personal vehicle.[7] These data are again presented in four panels for each section of the Coastal Bend, with Nueces County appearing last due to its multiple evacuation/risk zones. These data are presented in terms of households because research shows that people generally evacuate as a household, not individuals; that makes households the meaningful social unit when considering evacuation.[8] In addition to presenting the numbers of households without a vehicle by zone, the totals for all zones and for the county are presented. The final column represents total estimated households in each county, and all percentages are based on the total number of county households.

Given the variable sizes of household populations in Coastal Bend counties, there are also considerable variations in the numbers (and percentages) of household that do not have access to their own vehicle across the counties. Nearly 4 percent of the households in Calhoun County do not have access to their own vehicle, and all of these households are in either the highest-risk zone, A1, or Zone A. While 5 percent of Victoria County's households do not have access to their own vehicle, fortunately most are around the city of Victoria itself and not in evacuation/risk zones. An estimated 438 households, or nearly 5 percent of Aransas County's households, do not have a vehicle, and all of these households are in Zone A. Together, these households represent over 1,100 individuals.

[7] Since the ACS is based on sample data, there can be rather large margins of error associated with these relatively small percentages of the whole population. Therefore, these statistics should be used with caution. This does not mean that they can be ignored or dismissed. Rather, the project team suggests erring on the side of caution.

[8] While households are meaningful in this context, to get a full appreciation of the numbers of individuals in these households, one can multiply them by the average household size for each county: Calhoun: 2.79, Victoria: 2.75, Aransas: 2.56, Refugio: 2.64, San Patricio: 2.84, Kenedy: 3.68, Kleberg: 2.70, and Nueces: 2.72.

Table 3. Households without a Vehicle for Coastal Bend Counties by Hurricane Evacuation/Risk Zone.

County		Zone A1	Zone A	Zone B	Zone Totals	County total	Total Co. HHs
Calhoun	Estimate	180	110	0	290	290	7,733
	% Co. HHs.	2.3%	1.4%	0.0%	3.8%	3.8%	100.0%
Victoria	Estimate	n/a	67	19	86	1,626	32,734
	% Co. HHs.		0.2%	0.1%	0.3%	5.0%	100.0%

County		Zone A	Zone B	Zone C	Zone Totals	County total	Total Co. HHs
Aransas	Estimate	438	n/a	n/a	438	438	9,529
	% Co. HHs.	4.6%			4.6%	4.6%	100.0%
Refugio	Estimate	19	177	13	209	218	2,694
	% Co. HHs.	0.7%	6.6%	0.5%	7.8%	8.1%	100.0%
San Patricio	Estimate	475	23	100	598	1,435	23,246
	% Co. HHs.	2.0%	0.1%	0.4%	2.6%	6.2%	100.0%

County		Zone A	Zone B	Zone C	Zone Totals	County total	Total Co. HHs
Kenedy	Estimate	13	0	0	13	13	152
	% Co. HHs.	8.6%	0.0%	0.0%	8.6%	8.6%	100.0%
Kleberg	Estimate	9	317	n/a	326	979	10,958
	% Co. HHs.	0.1%	2.9%		3.0%	8.9%	100.0%

County		Zone A1	Zone A2	Zone A3	Zone B	Zone C	Zone & Co. Totals	Total Co. HHs
Nueces	Estimate	156	1,695	1,268	1,508	5,607	10,234	128,857
	% Co. HHs.	0.1%	1.3%	1.0%	1.2%	4.4%	7.9%	100.0%

Just over 8 percent of Refugio County's households do not have their own vehicle, and nearly all are in evacuation zones, particularly concentrated in Zone B. While the majority of San Patricio County's households without their own vehicle are not in evacuation zones, it is still estimated that nearly 600 of these households (approximately 1700 individuals) are located in hurricane evacuation/risk zones, with the majority of these in the highest-risk zone, Zone A. In Kenedy County, it is estimated that 13 of its 152 households do not have their own vehicle, and all of these are in evacuation/risk zones. Indeed, all are in Zone A. Similar to San Patricio County, the majority of Kleberg County's households without a vehicle are not in evacuation/risk zones. However, over 300 are, with the majority in Zone B.

Again, given its population size, it is not surprising that Nueces County has the largest number of households without their own vehicle, but it perhaps is surprising that nearly 8 percent of its households do not have a vehicle. This is a relatively high percentage when compared to other counties. While these households fall into all evacuation zones, over 3,100 households (representing nearly 8,500 individuals) do fall into the highest-risk zone, Zone A. These households are highly vulnerable and will need to evacuate early in the process.

To further facilitate evacuation planning at the local level, the Coastal Bend HES *Planning Atlas* includes a variety of mapping options to better identify where households without vehicles are likely to be located. Figure 5, for example, displays the 5-year ACS data, at the census block group level, for the estimated number of households that lack a vehicle. This layer is displayed partially transparent so that some features from the base map are more visible. In this case, the Layer List box is visible, indicating that the ***Social Vulnerability*** layer for ***housing units with no vehicle*** is active. Block groups are shaded such that those with progressively higher numbers of households without a vehicle appear in progressively darker blue.

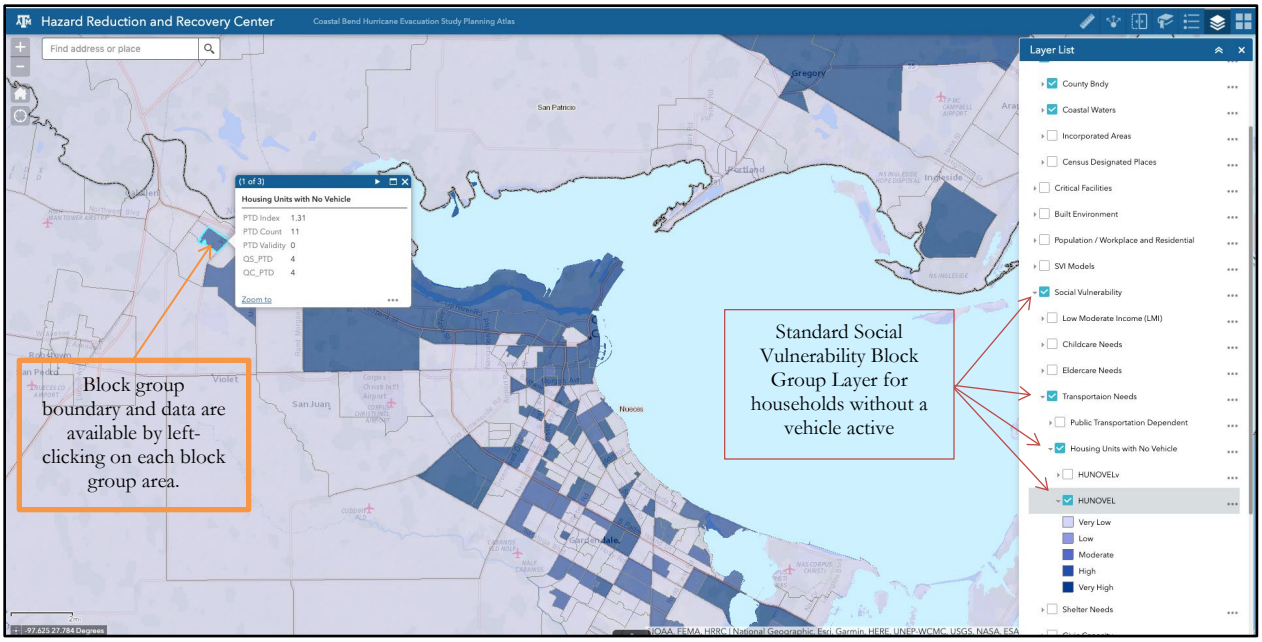

Figure 5. Standard Social Vulnerability Block Group Map for Households without a Vehicle.

To get a better idea of the numbers within each block group, the user can left-click on any block group, and a dialog box will pop up outlining the block group selected and indicating the estimated number of households without a vehicle in the area. Block groups are somewhat like neighborhoods in urban areas, such as in Corpus Christi and even Portland, but in rural areas such as areas north of Gregory or to the southwest of Corpus Christi, the block groups can be very large.

Figure 6 displays the same areas as Figure 5, but now an even more refined social vulnerability model data layer is displayed. Specifically, these data attempt to estimate where households without a vehicle are likely to be concentrated; however, in this case, the block group data have been filtered to better capture where, within block groups, the populations with specific attributes are likely to be concentrated. The same color scheme is employed; the darker the blue, the more densely concentrated are households that do not have a vehicle. As with the block group polygon data, these mapping layers are much more useful in areas where population itself is more concentrated. The mapping layers are also less useful in the more rural areas of the Coastal Bend counties.

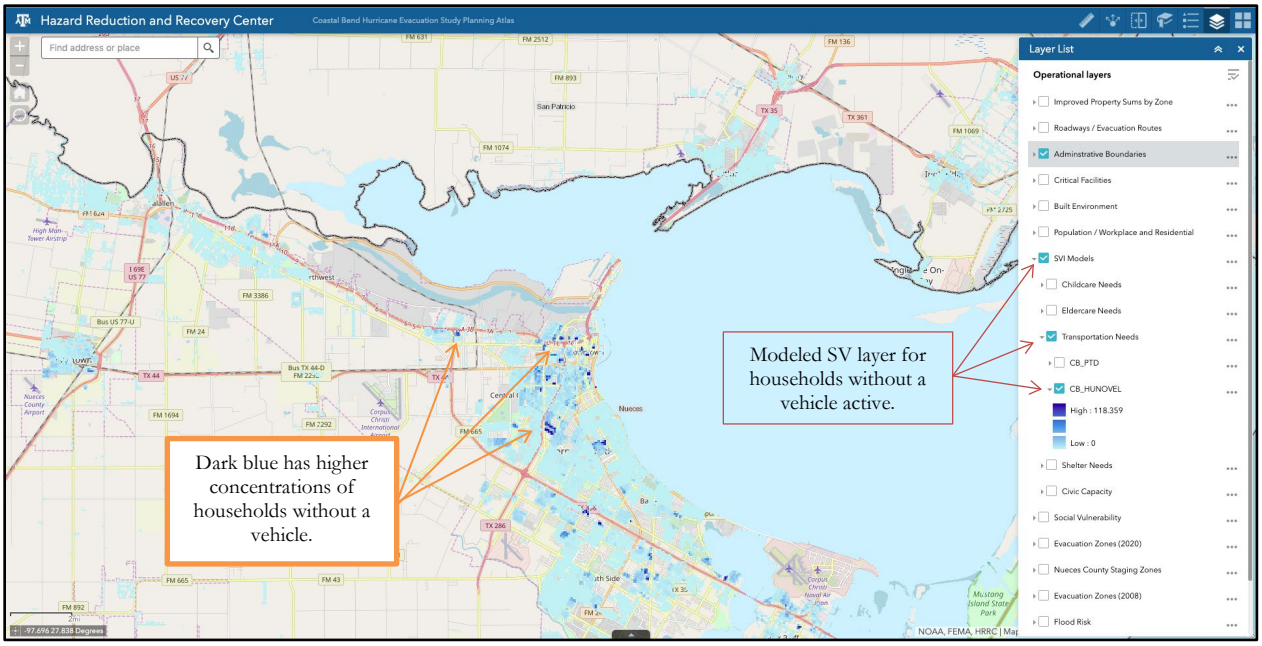

Figure 6. Modeled Social Vulnerability (SV) Data for Households without a Vehicle.

As with all data based on population estimates, they should be used with caution. The goal here is simply to estimate where concentrations of vulnerable populations are located. Therefore, this should be but the first step in developing a full evacuation plan for each county. The next step is to use these estimated locations to target planning efforts by identifying local organizations, churches, schools, and other groups. These groups can help reach into these neighborhoods to identify these households and develop strategies to ensure that help gets to these households when the area is threatened by a hurricane. ***In other words, these and other detailed maps offered in the Atlas should be viewed as tools to help identify where concerted outreach efforts should be targeted for further planning efforts, not an end to the planning process.***

Table 4 takes the analysis of populations potentially needing transportation assistance a bit further by estimating the population of elderly households within each evacuation zone in each county. For the purposes of this analysis, the project team followed the convention of identifying elderly households as those households in which the head of household is 65 years or older. This, of course, does not mean that all of these households will need transportation assistance; however, the literature strongly suggests that elderly households, on the whole, are less likely to evacuate, in part because they are slower to respond and/or have greater difficulty responding to evacuation calls.

The data in Table 4 are constructed and structured in a manner similar to those in the previous tables. These are household data, not individual data, representing the numbers of elderly households by zone, for all zones combined, and for the county. The final column again presents the counts of all county households, and the percentages in the table represent the relative percentages of these households when compared to all county households.

Table 4. Elderly Households in Coastal Bend Counties by Evacuation/Risk Zone.

County		Zone A1	Zone A	Zone B	Zone Totals	County Totals	Total Co. HHs
Calhoun	Estimate	1,828	460	79	2,367	2,367	7,733
	% Co. HHs.	23.6%	5.9%	1.0%	30.6%	30.6%	100.0%
Victoria	Estimate	n/a	485	195	680	9,660	32,734
	% Co. HHs.		1.5%	0.6%	2.1%	29.5%	100.0%

County		Zone A	Zone B	Zone C	Zone Totals	County Totals	Total Co. HHs
Aransas	Estimate	4,098	n/a	n/a	4,098	4,098	9,529
	% Co. HHs.	43.0%			43.0%	43.0%	100.0%
Refugio	Estimate	227	542	186	955	1,016	2,694
	% Co. HHs.	8.4%	20.1%	6.9%	35.4%	37.7%	100.0%
San Patricio	Estimate	2,249	143	1,285	3,677	6,564	23,246
	% Co. HHs.	9.7%	0.6%	5.5%	15.8%	28.2%	100.0%

County		Zone A	Zone B	Zone C	Zone Totals	County Totals	Total Co. HHs
Kenedy	Estimate	68	0	0	68	68	152
	% Co. HHs.	44.7%	0.0%	0.0%	44.7%	44.7%	100.0%
Kleberg	Estimate	271	1,500	n/a	1,771	2,671	10,958
	% Co. HHs.	2.5%	13.7%		16.2%	24.4%	100.0%

County		Zone A1	Zone A2	Zone A3	Zone B	Zone C	Zone & Co. totals	Total Co. HHs
Nueces	Estimate	1,614	5,464	3,869	5,893	17,287	34,127	128,857
	% Co. HHs.	1.3%	4.2%	3.0%	4.6%	13.4%	26.5%	100.0%

Even a brief overview of these estimates suggests that much higher concentrations of elderly households are in each of these counties when compared to households without a vehicle. Kleberg and Nueces Counties are at the low end, with approximately 25 percent of their households being classified as elderly, and Kenedy and Aransas Counties are at the other extreme, with over 40 percent of their households being so classified. In both Calhoun and Victoria Counties, around 30 percent of their households are elderly households; however, there are major differences in their distributions in evacuation/risk zones. Not only are all of Calhoun County's elderly households located in evacuation/risk zones, the vast majority, in excess of 1,800, are in the highest-risk zone, Zone A1. Given the nature of Victoria County's evacuation zones, it is not surprising to have a relatively small proportion of the county's elderly households in these zones; however, it is estimated that 680 elderly households are located in high-risk zones, with the highest number being in Zone A.

Just over 4,000, or 43 percent, of Aransas County's households are elderly households. Given Aransas County's hurricane risk, they are all in evacuation/risk Zone A. In Refugio County, nearly 38 percent of households are elderly, and the vast majority of these are located in one of its three evacuation zones, with the highest estimated concentration of 542 in Zone B. While San Patricio County has a lower relative percentage of elderly households at just over 28 percent, it has relatively high numbers

of elderly households in its evacuation zones. Indeed, nearly 2,250 estimated elderly households are just in Zone A, and overall there are over 3,600 elderly households in all three zones.

In Kenedy County, an estimated 68 elderly households are in Zone A, and over 1,700 elderly households are in Zones A and B in Kleberg County, with the majority (1,500) estimated to be in Zone B. While, Nueces County has, next to Kleberg County, the lowest percentage of households classified as elderly, given its very large population, the numbers of elderly households in its highest-risk evacuation zones are of great concern. An estimated 1,614 elderly households are in Zone A1, 5,464 are in Zone A2, and 3,869 are in Zone A3, meaning almost 11,000 elderly household are in the highest-risk evacuation zones in Nueces County. Furthermore, an additional estimate of almost 6,000 elderly households are in Zone B.

As with the case of households without a vehicle, the Coastal Bend HES *Planning Atlas* includes both block group polygon social vulnerability mapping tools for elderly households and higher-resolution modeled social vulnerability mapping tools. Figure 7 displays the standard social vulnerability mapping layer for elderly households. In this map, the darker the green, the higher the concentration of elderly households in the block group.

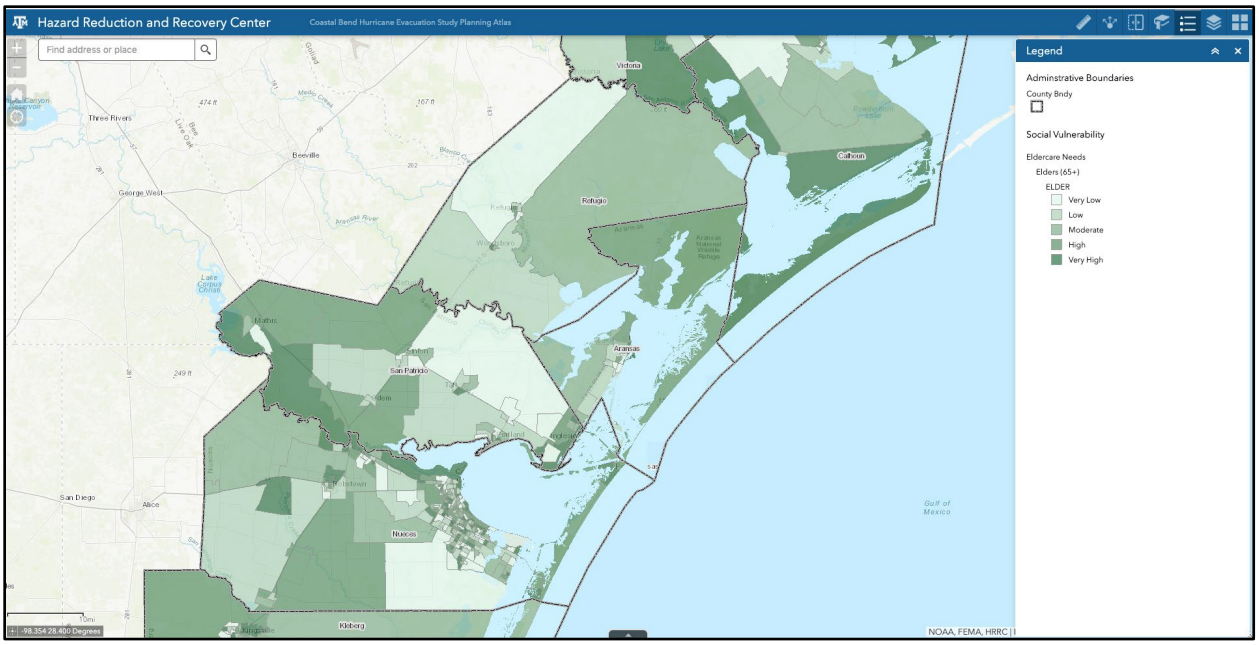

Figure 7. Social Vulnerability Map Layer for Elderly Households in Census Block Groups.

In light of the relatively high absolute number of households that are without their own vehicles, as well as the numbers and percentages of elderly households, it will be important for officials to work with and through local community and neighborhood organizations, churches, and other organizations to identify, reach out to, and help these households understand their hurricane risks and

develop plans to address evacuation issues.[9] Registries identifying potential elderly persons that may have difficulty evacuating already exist, which is an excellent start.

Again, the Coastal Bend HES *Planning Atlas* provides extensive data to help identify areas where vulnerable populations, such as elderly households and households without vehicles, are located. Additionally, for example, the *Atlas* can identify areas with high concentrations of households that are below the poverty level, single-parent households, or even elderly households that are also below the poverty level. Many of these households will also have difficulties during an evacuation and after a disaster. County officials and stakeholders are encouraged to use the *Planning Atlas* to help identify other areas with high concentrations of vulnerable populations. But as noted previously, using these data to identify areas with vulnerable households represents just the first step. Planners must work with the local community and neighborhood organizations, churches, and grassroots organizations to identify vulnerable households. These organizations can also help in developing plans to address pre- and post-disaster needs. The organizations can, for example, be critical to getting information out regarding evacuation planning, staging areas for buses, and other approaches to help move vulnerable households and individuals out of harm's way, as well as targeting evacuation programs and information.

[9] More than one jurisdiction has such a registry or has worked with an organization seeking to keep and maintain such a registry. These data were not made available to the evacuation study team and have not been included in this analysis.

4. Households in Mobile Homes, Travel Trailers, and Recreational Vehicles

Mobile homes, sometimes termed manufactured housing, and travel trailers are highly vulnerable structures due to the nature of their construction, even when these structures are secured using some form of tiedowns. Not only are they highly vulnerable in surge and flooding conditions, but they can be particularly unsafe in high winds generated by hurricanes ***and*** tropical storms. Similarly, high-profile RVs are also relatively unsafe in tropical storm force and hurricane winds. Therefore, the Coastal Bend HES team recommends that evacuations be called for ***all*** households residing in mobile homes, travel trailers, and RVs in all areas of Coastal Bend counties (in and outside hurricane risk/evacuation zones) whenever an area is subject to tropical storm force winds or higher.

To get a sense of the numbers of households residing in these kinds of structures, two techniques were employed:

- The first approach uses the ACS data collected by the U.S. Census about types of housing units (HUs) found in each county.
- The second approach triangulates data from a variety of sources to locate, map, and ultimately derive a count of these structures in each county.

Throughout this section, the term *mobile home* is used in a generic fashion, to represent mobile homes, travel trailers, and RVs since the U.S. Census also categorizes these housing units in this manner and the mapping strategy used here also captured the data in this manner.

Table 5 presents statistical data derived from the 2013–2017 5-year ACS estimating the numbers of mobile homes and similar structures (trailers and RVs) for each of the eight Coastal Bend counties by evacuation zone and for the overall county. The project team chose to present these data by evacuation zone and for the whole county not because they think the residents of these kinds of structures should be evacuated by zone. Residents of these structures should be urged to evacuate in all Coastal Bend counties regardless of their location inside or outside hurricane evacuation/risk zones. These structures are even more vulnerable if they are located in evacuation zones, so providing these data by zones captures the number of these highly vulnerable and relatively unsafe structures that are subject to surge and wind hazard threats.

As discussed in the population section, using census data to derive estimates of the number of people/households or mobile homes in this manner can be difficult because the boundaries of census units, such as blocks, block groups, or tracts, do not conform to the evacuation zone boundaries. This makes determination of how many structures are actually in specific evacuation zones subject to error. In order to derived the numbers of mobile homes per zone, the smallest census areal units for which theses data are available—block groups—were employed, and if the centroid of the block group fell in an evacuation zone, all the mobile home units (MHUs) of that block group were assigned to that specific evacuation zone.

Table 5. Estimates of Households in Mobile Homes by Evacuation/Hurricane Risk Zone for Coastal Bend Counties Using 2013–2017 American Community Survey Data.

County	Estimate	Zone A1	Zone A	Zone B	County MH units	Total Co. HU
Calhoun	Mobile Hm Units	1,658	195	75	1,928	11,837
	% of Co. HUs.	14.0%	1.6%	0.6%	16.3%	100.0%
	Est. Occupied MHUs	924	109	42	1073	
Victoria	Mobile Hm Units	n/a	440	166	4,046	36,507
	% of Co. HUs.		1.2%	0.5%	11.1%	100.0%
	Est. Occupied MHUs		361	136	3322	

County	Estimate	Zone A	Zone B	Zone C	County MH units	Total Co. HU
Aransas	Mobile Hm Units	3,380	n/a	n/a	3,380	16,002
	% of Co. HUs.	21.1%			21.1%	100.0%
	Est. Occupied MHUs	2055			2055	
Refugio	Mobile Hm Units	53	206	119	395	3,734
	% of Co. HUs.	1.4%	5.5%	3.2%	10.6%	100.0%
	Est. Occupied MHUs	32	123	71	236	
San Patricio	Mobile Hm Units	936	11	143	2,633	27,492
	% of Co. HUs.	3.4%	0.0%	0.5%	9.6%	100.0%
	Est. Occupied MHUs	709	8	108	1993	

County	Estimate	Zone A	Zone B	Zone C	County MH units	Total Co. HU
Kenedy	Mobile Hm Units	9	0	0	9	253
	% of Co. HUs.	3.6%	0.0%	0.0%	3.6%	100.0%
	Est. Occupied MHUs	4	0	0	4	
Kleberg	Mobile Hm Units	154	165	n/a	864	13,194
	% of Co. HUs.	1.2%	1.3%		6.5%	100.0%
	Est. Occupied MHUs	128	137		719	

County	Estimate	Zone A1	Zone A2	Zone A3	Zone B	Zone C	County MH units	Total Co. HU
Nueces	Mobile Hm Units	318	489	1,024	280	2,742	4,853	146,962
	% of Co. HUs.	0.2%	0.3%	0.7%	0.2%	1.9%	3.3%	100.0%
	Est. Occupied MHUs	271	416	872	238	2335	4,133	

An additional problem associated with these data is in determining whether or not a mobile home is actually occupied by a household. To determine the number of occupied mobile homes, and hence the number of households residing in mobile homes or their equivalents, an occupancy rate was calculated for each county based on the estimated number of occupied mobile homes, divided by the estimated number of mobile home housing units for each county.[10] This occupancy rate was then assumed to hold across evacuation zones for each county.

Again, Table 5 presents the estimated number of mobile homes and occupied mobile homes in each evacuation zone for each county in the Coastal Bend. The final column in each panel or part of the table presents the total number of housing units in each county. The percentages represent the percentage of total county housing units that are mobile homes and located in specific areas. The three values, from top to bottom, in the second-to-last column in each panel represent the total estimated number of mobile home units in each county, the percentage of total housing units that are mobile home units, and the estimated number of occupied mobile homes, respectively. Since mobile homes are generally occupied by a single household, the latter number also represents the total number of households residing in mobile homes. This is the estimated number of households that should evacuate and seek safer shelter whenever a tropical storm or hurricane threatens the area.

Based on these ACS estimates, Nueces County has the highest number of mobile homes at 4,853, but that number represents only 3.3 percent of all its housing units. The number of occupied mobile homes is estimated at 4,133; therefore, 4,133 households are estimated to reside in mobile homes that must be evacuated under any tropical storm/hurricane threat. While there are significant numbers in Zone A, substantial proportions of these units are found in Zone B and C combined. ***It will be critical to reach out to these households and help them create an evacuation plan that ensures that they seek safer shelter whenever the area is threatened.***

While other counties throughout the Coastal Bend area have much smaller populations than Nueces County, many of these counties have substantial numbers of households residing in mobile homes, oftentimes representing significant percentages of each county's housing units. For example, over 20 percent of Aransas County's housing units are mobile homes, and over 2,000 households are estimated to occupy these units. Similarly, 16.3 percent of Calhoun County's housing units (estimated to have 1,073 occupied by households), 11.1 percent of Victoria County's (estimated to have 3,322 occupied by households), 10.6 percent of Refugio County's (estimated to have 236 occupied by households), and 9.6 percent of San Patricio County's (estimated to be occupied by 1,993 households) are in mobile homes or similar structures. In the low range, approximately 6.5 percent of Kleberg County's housing units are mobile homes, of which 719 are estimated to be occupied. Kenedy County is estimated to have only 9 mobile home housing units, 4 of which are estimated to be occupied.

Again, in many counties, significant numbers of household reside in mobile homes, travel trailers, and RVs that are in lower-hurricane risk/evacuation zones (B or C) or are outside these zones. This does not mean that these households are not at risk. Indeed, substantial efforts must be placed on educating these households that they should evacuate and seek safer shelter under any tropical storm or hurricane threat.

[10] The estimate mobile home occupancy rates for each county were as follows: Calhoun: 0.557, Victoria: 0.821, Aransas: 0.608, Refugio: 0.597, San Patricio: 0.757, Kenedy: 0.444, Kleberg: 0.832, and Nueces: 0.852. These were derived from the ACS S2504 table based on 2013–2017 5-year estimates.

Significant portions of the Coastal Bend area were subject to the impacts of Hurricane Harvey, and given the highly vulnerable nature of mobile homes, travel trailers, and RVs, these structures may have had significant damage, altering their numbers and locations. Also, these changes might not be fully registered in the ACS statistics. As a consequence, the project team undertook special efforts to develop additional data on these kinds of housing units. To identify these structures, various data were compiled, and extensive work with Google mapping resources was undertaken. Specifically, the team employed Google, Google Maps, Google Imagery Web Map Services, and the Texas Imagery Service Texas Natural Resources Information System (associated with the Texas A&M Forest Service). The latter in particular provided access to high-resolution imagery from Google, with multiple years of mapping data for the region, allowing the project team to capture changes, along with special images captured just after Hurricane Harvey.

Use of these mapping data allowed mobile parks, clusters, and even more isolated mobile homes throughout the Coastal Bend area to be identified and mapped. As part of this process, Q-GIS[11] was employed to geo-locate/reference each structure. All units or structures were classified into one of three types of mobile homes:

- Mobile homes (larger mobile homes, generally appearing to be in long-term or more fixed locations).
- Trailers (smaller travel trailers with clearly definable wheels that could easily be transported).
- RVs.

If structures appeared in clusters, other sources such as Google and Google Maps were used to identify if the cluster represented a recognized mobile home or RV park. If the cluster was some form of park, these data were recorded with the structures. Due to the predominant use of aerial photographs, an error in identifying the type of mobile home is inherent. For the purposes of the *Planning Atlas* and this data presentation, the project team followed the U.S. Census approach of simply classifying all mobile homes, travel trailers, and RVs as mobile homes. The resulting data developed by this process greatly enhance the ability to identify where these structures are located.

Figure 8, Figure 9, and Figure 10 show examples of the mobile home data from the *Planning Atlas* website. Figure 8 displays the general data for Coastal Bend counties. At this level of resolution, the dots tend to blend together but offer a general idea of the dispersion and concentrations of mobile homes throughout the region. These data are available in the Built Environment folder in the *Planning Atlas*. Figure 9 zooms in to the Port Lavaca area in Calhoun County and shows the finer resolution of these data. In this figure, each dot represents a mobile home of some type. Clicking on the ellipsis (…) next to this layer, turning on pop-up boxes, and then clicking on one of the symbols bring up information such as the park name if available.

Figure 10 provides a very detailed view of the same park, with imagery in the background. In this case, the dots are located on top of the mobile homes in this park. The consistency between dot locations over mobile homes, travel trailers, or RVs can vary since parks change, and different images may have been used when undertaking the mapping efforts at various times during this project.

[11] Q-GIS is a free open source geographic information system (GIS). For information see: https://qgis.org/en/site/

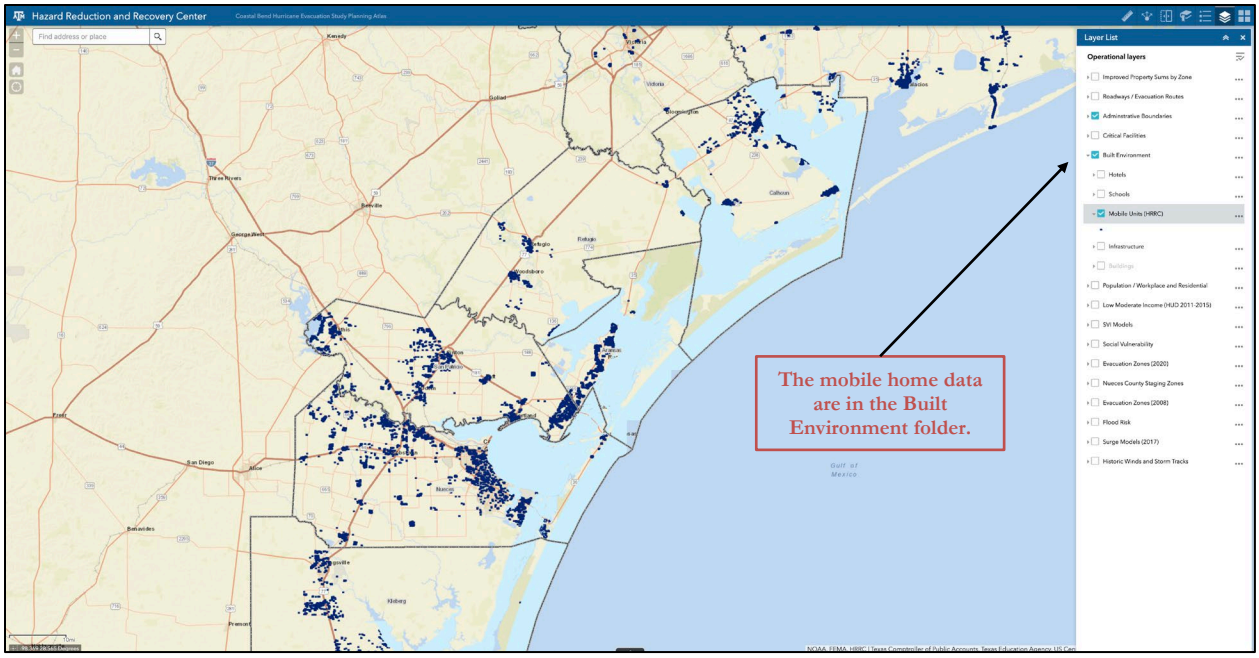

Figure 8. Mobile Home Locations in the Coastal Bend.

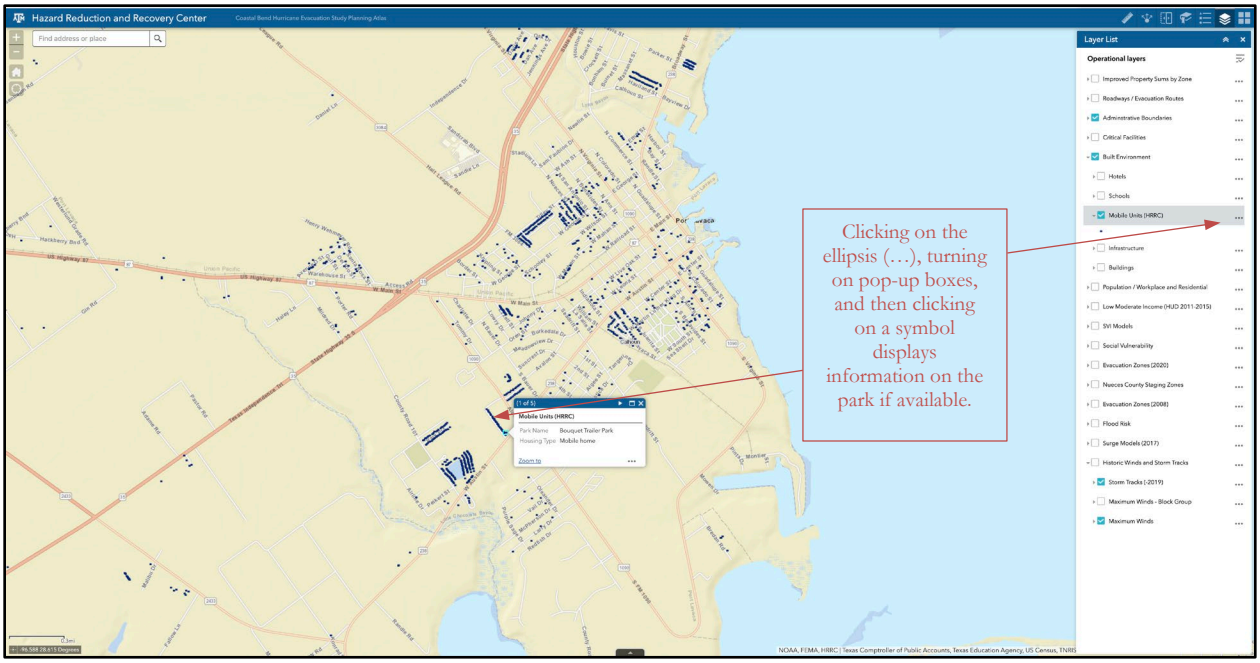

Figure 9. Detailed View of Mobile Home Data for Port Lavaca.

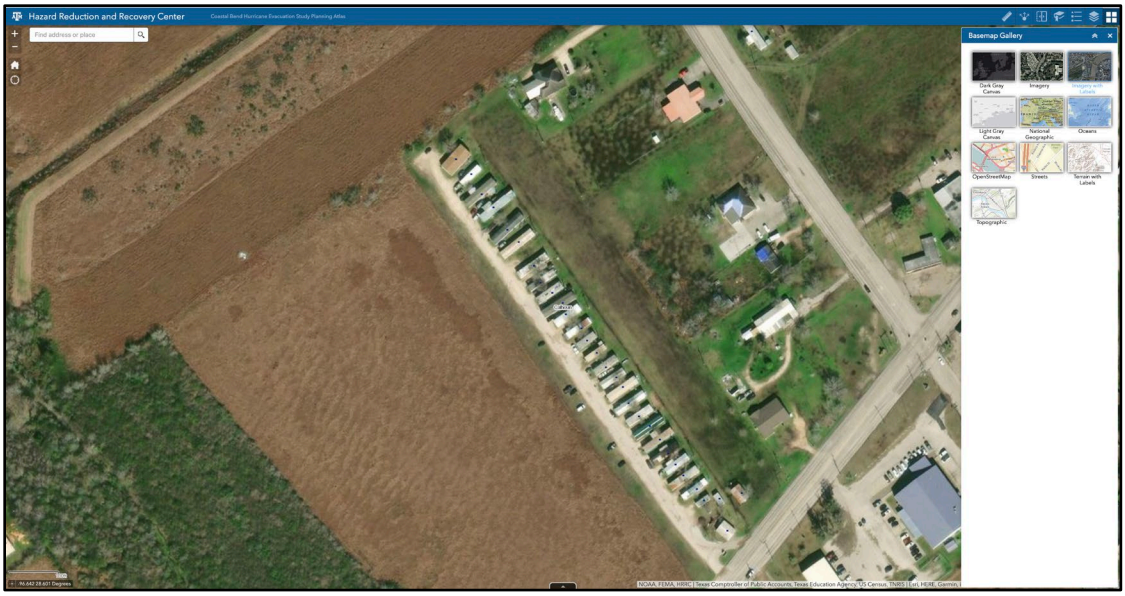

Figure 10. Closeup of Mobile Home Park near Port Lavaca.

Figure 11 displays the mobile home data for Victoria and Calhoun Counties, along with wind fields, based on historical storms (importantly, not including Hurricane Harvey[12]). The gray-shaded contours overlaid on the area represent wind speeds the area is likely to experience, suggesting that the entire area is subject to experiencing extremely high winds. All residents of mobile homes are subject to high levels of risk if they remain in these structures during wind-related events. Again, it is critical that households residing in these structures be encouraged to evacuate to safer structures for all windstorms that may threaten the Coastal Bend area.

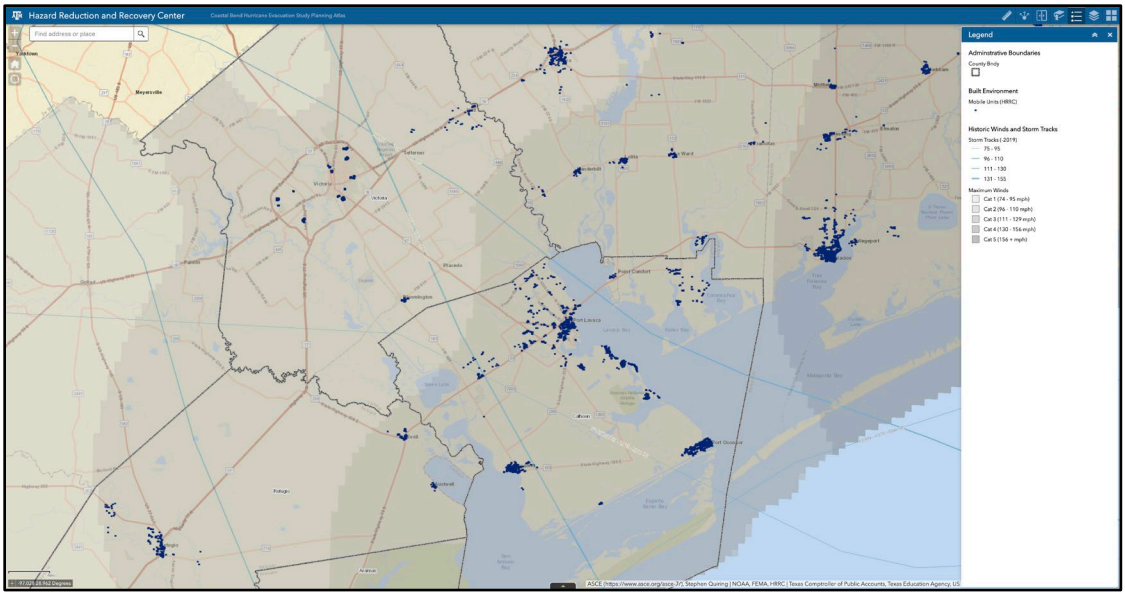

Figure 11. Mobile Home Locations, Maximum Winds, and Historical Storm Tracks for Victoria and Calhoun Counties.

[12] The wind data were created for the Texas Department of Emergency Management prior to Hurricane Harvey.

Table 6 displays the actual data created through the mapping process for the Coastal Bend counties. The table is structured in a manner similar to previous tables, with estimated counts of mobile home (mobile homes, travel trailers, and RVs) units for the entire county, each hurricane risk/evacuation zone, and outside these zones. Since these data have actually been geo-referenced, the estimates for each zone should have less error than those based on the census data estimates.

Table 6. Estimated Mobile Residents for Cameron, Willacy, and Hidalgo Counties.

County		Zone A1	Zone A	Zone B	Outside	Total
Calhoun	Total Units	2401	516	60		2977
	Est. Occupied	1337	287	33		1658
	Est. Individuals	3731	802	93		4626
Victoria	Total Units			16	1084	1100
	Est. Occupied			13	890	903
	Est. Individuals			36	2447	2484

County		Zone A	Zone B	Zone C	Outside	Total
Aransas	Total Units	6719				6719
	Est. Occupied	4085				4085
	Est. Individuals	10458				10458
Refugio	Total Units	383	109	87		579
	Est. Occupied	229	65	52		346
	Est. Individuals	604	172	137		913
San Patricio	Total Units	2465	102	155	2289	5011
	Est. Occupied	1866	77	117	1733	3793
	Est. Individuals	5299	219	333	4921	10773

County		Zone A	Zone B	Zone C	Outside	Total
Kenedy	Total Units			13		13
	Est. Occupied			6		6
	Est. Individuals			21		21
Kleberg	Total Units	324	702		703	1729
	Est. Occupied	270	584		585	1439
	Est. Individuals	728	1577		1579	3884

County		Zone A1	Zone A2	Zone A3	Zone B	Zone C	Total
Nueces	Total Units	1241	1350	1097	739	3727	8154
	Est. Occupied	1057	1150	934	629	3174	6944
	Est. Individuals	2875	3127	2541	1712	8633	18888

These counts represent mobile homes, but their occupancy status is unknown. Therefore, occupancy status is estimated using the occupancy rates[13] calculated using the ACS data discussed previously. This means that the estimated occupied mobile home units also represent the estimated number of households that should evacuate whenever the area is threatened by a tropical storm or hurricane.

[13] The estimated mobile home occupancy rates for each county are as follows: Calhoun: 0.557, Victoria: 0.821, Aransas: 0.608, Refugio: 0.597, San Patricio: 0.757, Kenedy: 0.444, Kleberg: 0.832, and Nueces: 0.852. These were derived from the ACS S2504 table based on 2013–2017 5-year estimates.

Additionally, while the project team believes that the household figure is the most appropriate to employ for planning efforts, they have also calculated the estimated numbers of individuals residing in these relatively unsafe structures by simply multiplying the occupied units by the average household size for each county.[14]

The first question is, of course, how these data compare to the data derived from the ACS data found in Table 5. The most obvious and significant difference is that, in general, the numbers are significantly ***greater*** than those derived from the ACS. Generally speaking, the estimated number of mobile homes tends to be significantly higher. Specifically, the numbers are double the ACS estimates in Aransas, Kleberg, and San Patricio Counties. Additionally, the numbers are 70 percent higher in Nueces County, 50 percent higher in Calhoun and Refugio Counties, and 40 percent higher in Kenedy County. The exception to this general rule is Victoria County, where the estimates are about 60 percent lower.

There may be a variety of reasons for these differences. The obvious first reason is that while the ACS data represent 5-year estimates for the period between 2013 and 2017, the team's data are derived from aerial and street view images 1–1.5 years after Hurricane Harvey. Much may have changed during this period. Second, there may be a difference in what kinds of housing units actually fall in the mobile home category between these assessments and those of the U.S. Census/ACS. An additional reason may be that the current data show the transitory population related to post-Harvey reconstruction (the U.S. Census generally underreports informal housing) or part of the tourist-based seasonal housing/population. However, given the slowness in recovery for many areas, it is unlikely that these increases are due to construction-related workers that perhaps have migrated to the area following Hurricane Harvey. The U.S. Census also goes to great lengths to capture seasonal housing, so this reason is unlikely. Regardless of the reason, the project team is quite confident of data counts and think it prudent, for safety reasons, to employ the higher estimates based on the ACS data for evacuation planning purposes.

Given the vulnerabilities of all households and individuals living in these kinds of structures, regardless of their location in or outside an evacuation zone, the data to focus on in Table 6 are in the final column in each panel. This column, from top to bottom, presents the estimated number of housing units in mobile homes (mobile homes, travel trailers, or RVs) for each county, the estimated number of these units that are occupied, and the estimated number of individuals living in these occupied housing units. For example, focusing on the numbers for Aransas County, these data suggest an estimate of just over 6,700 mobile homes in the county with 4,085 of these occupied by households, composed of nearly 10,500 individuals. Or, perhaps more cautiously, the estimate could be just over 4,000 households residing in mobile homes in the county, but that number may be as high as 6,700. Additionally, the mapping data presented in the *Planning Atlas* may provide a good idea of where these structures are likely to be located and concentrated. Now the issue is ensuring that individuals living in these kinds of residences clearly understand the nature of their vulnerability to the surge and wind associated with tropical storms and hurricanes.

[14] The average household size for each county is as follows: Calhoun: 2.79, Victoria: 2.75, Aransas: 2.56, Refugio: 2.64, San Patricio: 2.84, Kenedy: 3.68, Kleberg: 2.70, and Nueces: 2.72.

5. Critical Facilities, Built Environment, and Infrastructure Mapping Data

The HES project team has also assembled data from a variety of sources to generate mappable data related to critical facilities, features of the built environment, and infrastructure for use on the Coastal Bend HES *Planning Atlas* website. This section provides a brief overview of these data, data sources, and examples of the layers mapped using the *Atlas*. While the HES team has spot-checked some of the data associated with these data layers and—in the case of hotel/motel data and mobile home data—has invested considerable effort to improve and properly geo-locating them, the project team cannot attest to the accuracy of these data nor their geographic locations. Therefore, these data, particularly with respect to each facility's location, ***must*** be used with caution.

Critical Facilities

The critical facilities data include data on law enforcement facilities (police station branch offices, sheriff offices, etc.), fire stations and branches, emergency operations centers, EMS locations, hospitals, etc. These data come from a variety of sources, and often more detailed information on each facility is available via pop-ups. The labels used for each are the same as those appearing in the *Atlas* and are as follows:

1. **Police:** 59+ locations. These data include police stations, branch offices, and sheriff offices for county and city locations. Data sources include SimplyAnalytics[15] and Esri Koordinates.[16]
2. **Fire Stations:** 88 locations. The data set includes detailed North American Industry Classification System descriptions for each location. For instance, the data set tells if ambulance and fire service is available, whether it is an EMS location, whether volunteers work, and the number of people (information is restricted for some locations). Data sources are the Hurricane Harvey Response website[17] and Esri Kordinantes.[16]
3. **Local EOC:** 18 locations of emergency operations centers (EOCs). Data sources include Hurricane Harvey Response[17] and NAVTEQ.[18]
4. **EMS:** 60 locations. Data sources include Hurricane Harvey Response[17] and NAVTEQ.[18]
5. **Urgent Care:** 10 urgent medical centers. Data were collected in 2009. Data sources include Hurricane Harvey Response[17] and NAVTEQ.[18]
6. **Nursing Homes:** 38 locations. The data set contains population, some description of the nursing care facilities, website or other type of contact, state license number, number of beds, and source data (mostly 2015), among other information. Data sources include Hurricane Harvey Response.[17]
7. **Hospitals:** 48 locations. The data set contains the type of hospital (e.g., general hospital, clinic, health/allied services, hospice, medical center, etc.). The data set also contains the number of

[15] SimplyAnalytics, published by Geographic Research, Inc.
[16] Esri Koordinates, published by Esri at https://koordinates.com.
[17] The Hurricane Harvey Response website provides geospatial data from authoritative sources where possible that can be useful to support community response and recovery to Hurricane Harvey. The data are available for download as CSV, KML, Shapefile, and accessible via web services to support application development and data visualization. The contacts are Jonathan Rayer with ArdentMC (security and defense solutions) at http://geoplatform.gov and Homeland Infrastructure Foundation-Level Data (HIFLD) for Hurricane Harvey at https://respond-harvey-geoplatform.opendata.arcgis.com.
[18] NAVTEQ, published by HIFLD.

employees for each location, and whether it is a branch or single location, among other information. Data sources include ReferenceUSA[19] and SimplyAnalytics[13].

Figure 12 provides an example of these data.

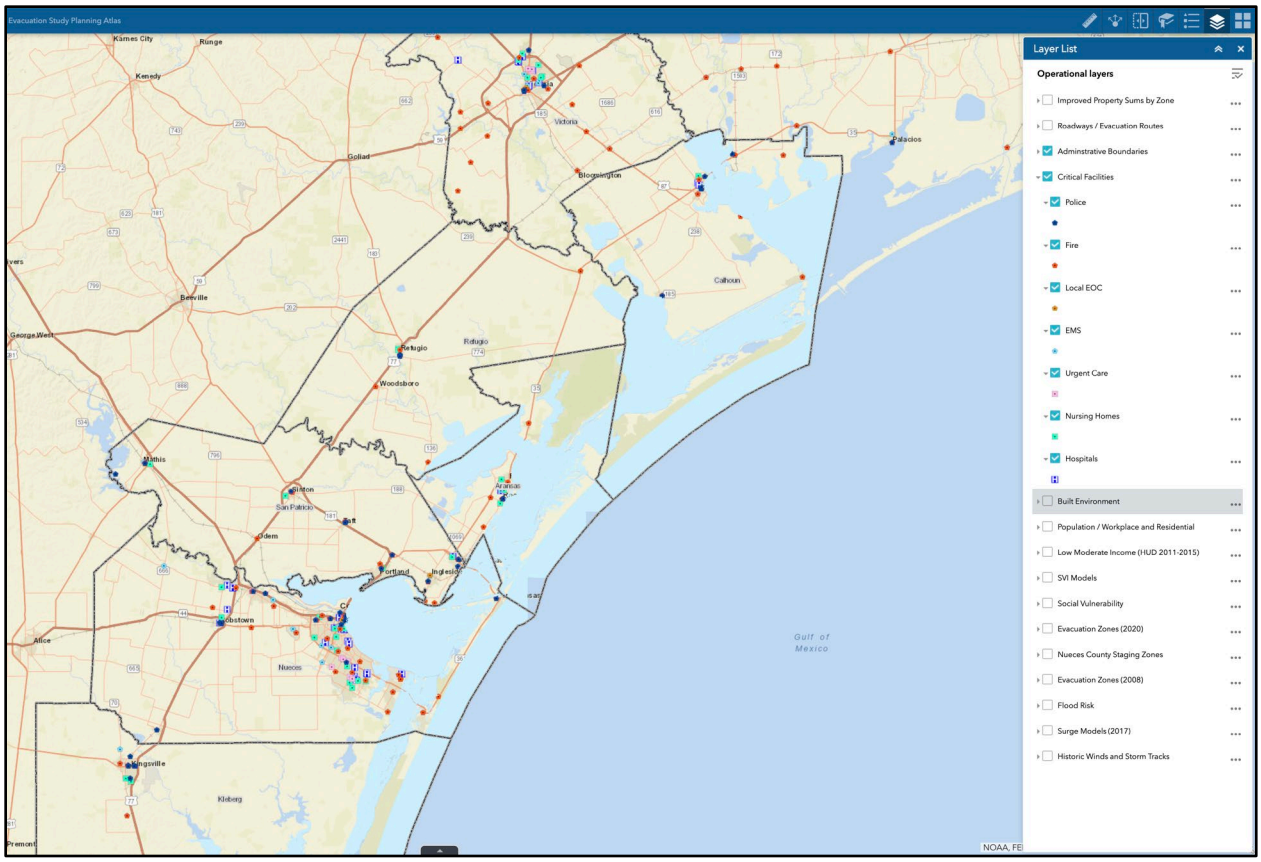

Figure 12. Critical Facilities Data.

Built Environment

The labels for the build environment are as follows:

1. **Schools**:

    a. **Public Schools:** all public schools in Texas except public charters and those with juvenile justice alternative education program and disciplinary alternative education program instructional types for the school year of 2019 to 2020, selected for Coastal Bend counties. The data source is the Texas Education Agency.
    b. **Charter Schools:** all public charter schools in Texas for the school year of 2019 to 2020, selected for Coastal Bend counties. The data source is the Texas Education Agency.

[19] ReferenceUSA, published by Infogroup (available at Texas A&M University Maps and GIS Services at http://tamu.libguides.com/gisdata).

c. **Private Schools:** 40 locations. This data set contains the number of students (enrollment), details about the levels (start grade and end grade), and whether it is full time. Source data vary, between 2009 and 2014, selected for Coastal Bend counties. The data source is ReferenceUSA, published by Infogroup.
d. **Daycare Centers:** 256 locations. Data contain detailed descriptions for each location (e.g., head start, before or after school hours, etc.) and the population. Data sources include Hurricane Harvey Response[17] and the Texas Department of Family and Protective Services.[20]
e. **ISD Boundaries:** 2018–2019 statewide school districts for Texas. The information was collected from all 254 county central appraisal districts and from the Texas Education Agency. Texas Legislative Council staff created the school district boundaries using the 2010 TIGER/Line Shapefile[21] as base geography and made further corrections to match the school district boundary updates and name changes for the map. These changes include lines that are not census geography. Changes to school district boundaries may include one or all of the following types: school district annexations or de-annexations; school district consolidations, deletions, or additions; boundary corrections to the Texas Legislative Council database; and boundary adjustments due to more spatially accurate data involving land parcels and survey data received from a county central appraisal district. The contact is the Texas Education Agency GIS administrator at GISAdmin@tea.state.tx.us.
f. **TEA Regions**[6]**:** Texas Education Service Center regions.

2. **Mobile Home:** see the discussion in earlier sections on the nature of these data and how they were generated.
3. **Hotels:** geocoded locations for all lodging for which operators must collect state hotel occupancy tax from guests. This includes hotels, motels, bed-and-breakfasts, condominiums, apartments, and houses renting space for overnight lodging. See the discussion in earlier sections.
4. **Buildings:** computer-generated building footprint data for the entire area. The source is Microsoft under the Open Data Commons Open Database License.

Figure 13 displays the school data from the Built Environment folder only since hotel and mobile home data have already been shown in Figure 4 and Figure 8, respectively. This example zooms in to Nueces, Kleberg, San Patricio, and Aransas Counties. Each type of school, including public and private schools and daycare facilities, has its own symbol and color. Additionally, the size of the symbol provides additional data on the relative enrollments at each school.

[20] Published by HIFLD for Hurricane Harvey Response.
[21] TIGER stands for, Topologically Integrated Geographic Encoding and Referencing and TIGER/Line is a format used by the United States Census Bureau to describe land attributes such as roads, buildings, rivers, and lakes, as well as areas such as census tracts. TIGER was developed to support and improve the Bureau's process of taking the Decennial Census.

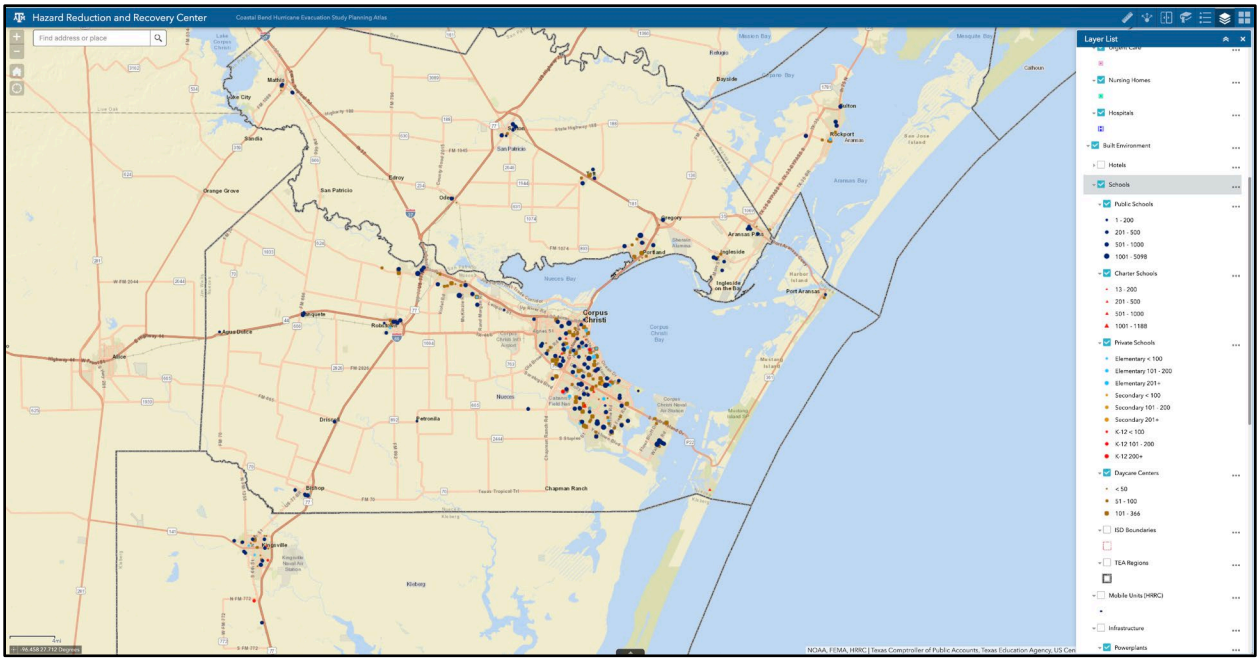

Figure 13. School Data Available in the *Planning Atlas*.

Infrastructure

The labels for infrastructure are as follows:

1. **Power Plants:** 36 locations. Operable electric-generating plants in the United States by energy source. This includes all plants that are operating, on standby, or short- or long-term out of service with a combined nameplate capacity of 1 MW or more. This includes summer and winter capacity, operations capacity, and description for the source of energy for most of the places (natural gas, natural gas combined with other sources, wind turbine, petroleum, etc.). The data sources are the U.S. Energy Information Administration EIA-860, Annual Electric Generator Report; EIA-860M, Monthly Update to the Annual Electric Generator Report; and EIA-923, Power Plant Operations Report.
2. **Wind Turbines:** The United States Wind Turbine Database provides the locations of land-based and offshore wind turbines in the United States. These data are collected and compiled from various public and private sources. The data source is the U.S. Geological Survey Energy Resources Program.
3. **Military Establishments:** U.S. Census TIGER line files. The data source is the U.S. Census.
4. **Airports:** data set created by the Texas Department of Transportation (TxDOT) Aviation Division and modified by the Transportation Planning and Programming Division's Data Analysis, Mapping, and Reporting Branch for planning and asset inventory purposes, as well as for visualization, county map book, and general mapping. This data set contains information about airport name, ownership, county, district, and Federal Aviation Administration (FAA) facility numbers. The data source is TxDOT.
5. **Airport Boundaries:** data set created by the TxDOT Aviation Division and modified by the Transportation Planning and Programming Division's Data Analysis, Mapping, and Reporting Branch for planning and asset inventory purposes, as well as for visualization, county map

book, and general mapping. This data set contains information about airport name, ownership, county, district, and FAA facility numbers. The data are valid as of 2012.

6. **Railroads:** data set created by the TxDOT Transportation Planning and Programming Division.

6. Estimated Job and Employee Residential Vulnerability

The U.S. Census's Economic Research Service is now providing a relatively new and important data set to the public. These data identify job locations and employee residential locations at a very fine resolution—the census block level. With these data, it is possible to get a relatively clear and accurate assessment of job and employee residential locations relative to hurricane evacuation zones.

Collectively, these data are known as the Longitudinal Employer-Household Dynamics Program's Origin-Destination Employment Statistical (LODES) data. These data are available for download from a website created and maintained by the U.S. Census known as OnTheMap (http://onthemap.ces.census.gov/). On the whole, these data capture the job and residential locations of all employees for which their employer pays unemployment insurance to the state. While these do not represent all employees, particularly in some areas, on the whole these data capture the vast majority of all workers in the United States. These data are available for most states for the years 2002–2017, and the data displayed on the *Planning Atlas* are for 2017. Specifically, within the LODES layer folder, data layers are provided for *Workplace Area Characteristics* and *Residence Area Characteristics*. The *Workplace Area Characteristics* layer provides data on the number of jobs located within a census block, while the *Residence Area Characteristics* layer provides data on the number of worker residences located within the census block. For each layer, the symbols provide an indication of the number of jobs or worker residences located in the census block. Using these data, it is possible to provide an estimate of the number of jobs and the number of employee residences within each of the evacuation zones.

"Fuzz" factors are added to these data that become increasingly evident the finer the resolution. For example, at the finest resolution, a particular job may not actually be displayed correctly in its specific block location; it may be randomly aligned to the adjacent block. However, as the user zooms out from the neighborhood, to a section of a city, to the city, and then county, the data are very accurate. This means that if the user has zoomed in to a very small section and sees two jobs, split between the boundary of Zones A and B, it may well be that both are actually in one or the other zone. On the other hand, when allocating all jobs to zones, the results will be quite accurate.

Figure 14 displays the job locations overlaid on evacuation zones for Nueces, San Patricio, and Aransas Counties. From this level of resolution, it is relatively easy to see that sizable percentages of jobs in these counties are located in evacuation zones. To better see how detailed these data are, Figure 15 displays the job locations for Port Aransas. At this level of resolution, the data can capture job locations at a fairly fine level of scale—at the census block level. However, the utility of these data depends on where the user is trying to map job locations. More specifically, these data work quite well in more urban places, where jobs and people are likely to be more densely located. Therefore, blocks themselves are likely to consist of rather small physical locations. However, when portraying job locations in more rural areas, where even census blocks tend to be quite large, the data are less useful.

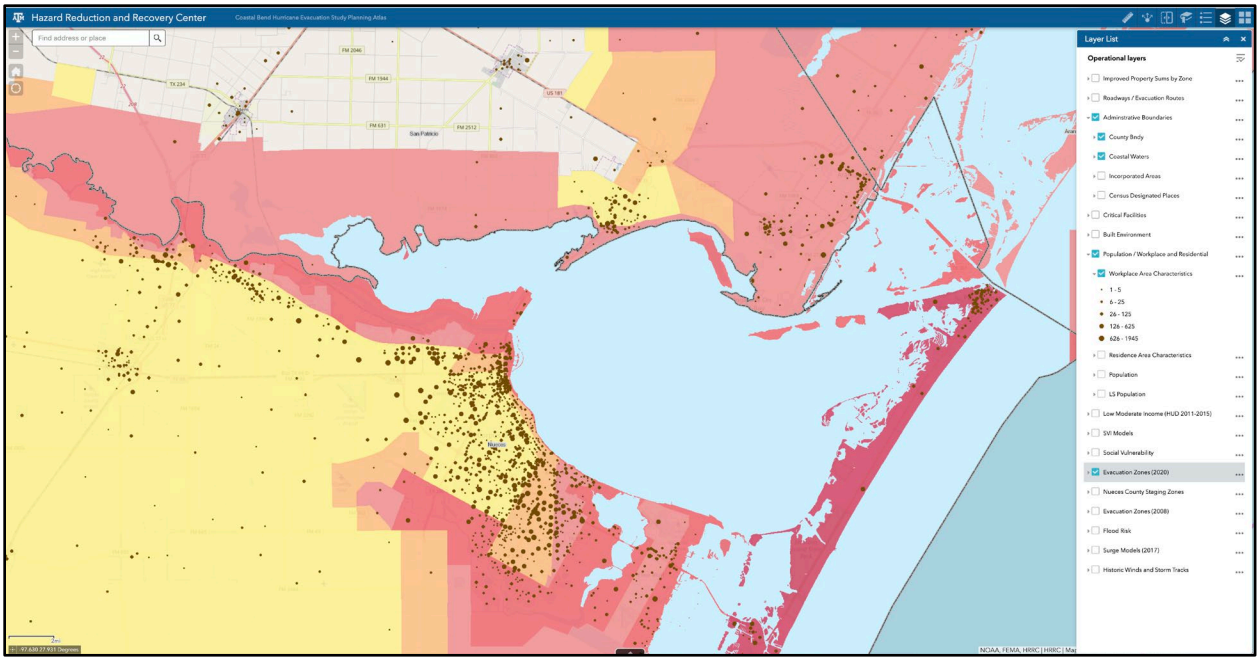

Figure 14. Job Locations and Hurricane Evacuation Zones for Nueces, San Patricio, and Aransas Counties.

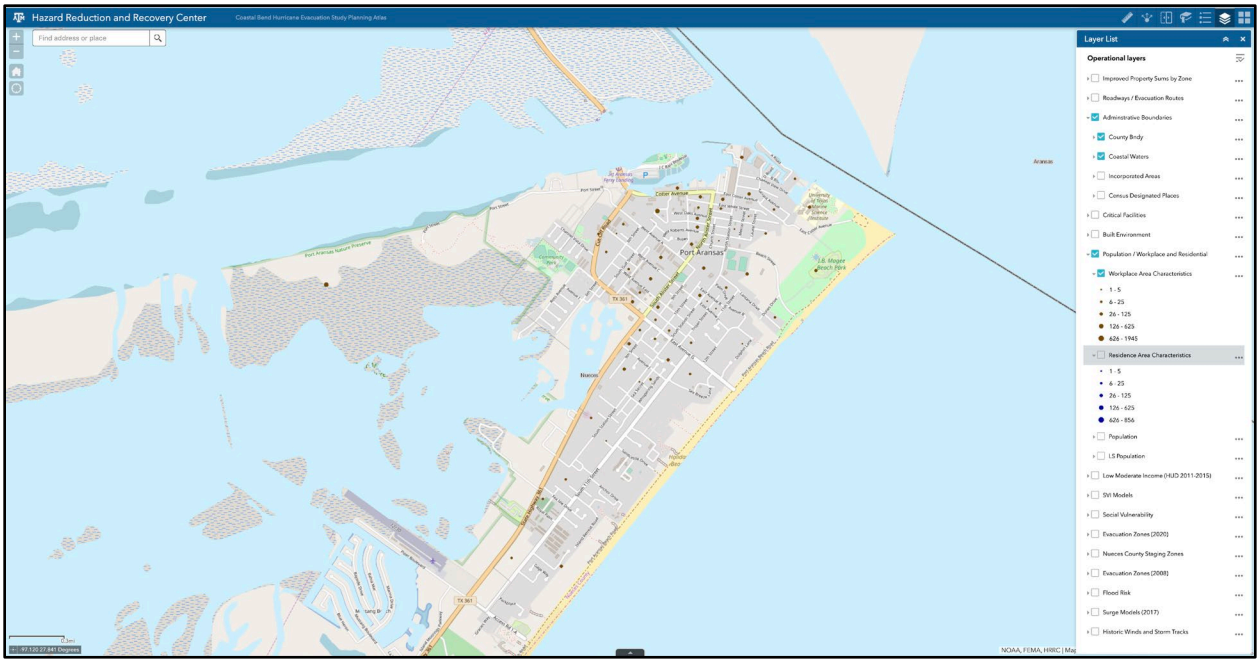

Figure 15. Job Locations in and around Port Isabel and South Padre Island.

The other side of the job/home equation is of course where the workers or employees filling these jobs reside. Figure 16 displays the residential locations for workers/employees in Nueces, San Patricio, and Aransas Counties. Again, these data have been overlaid on the hurricane risk/evacuation zones for these counties. These data suggest that significant numbers of workers/employees throughout these counties live in relatively high-risk zones. This is most clearly evident in Aransas County, but even in Nueces County there are significant proportion of residential locations in Zones A and B.

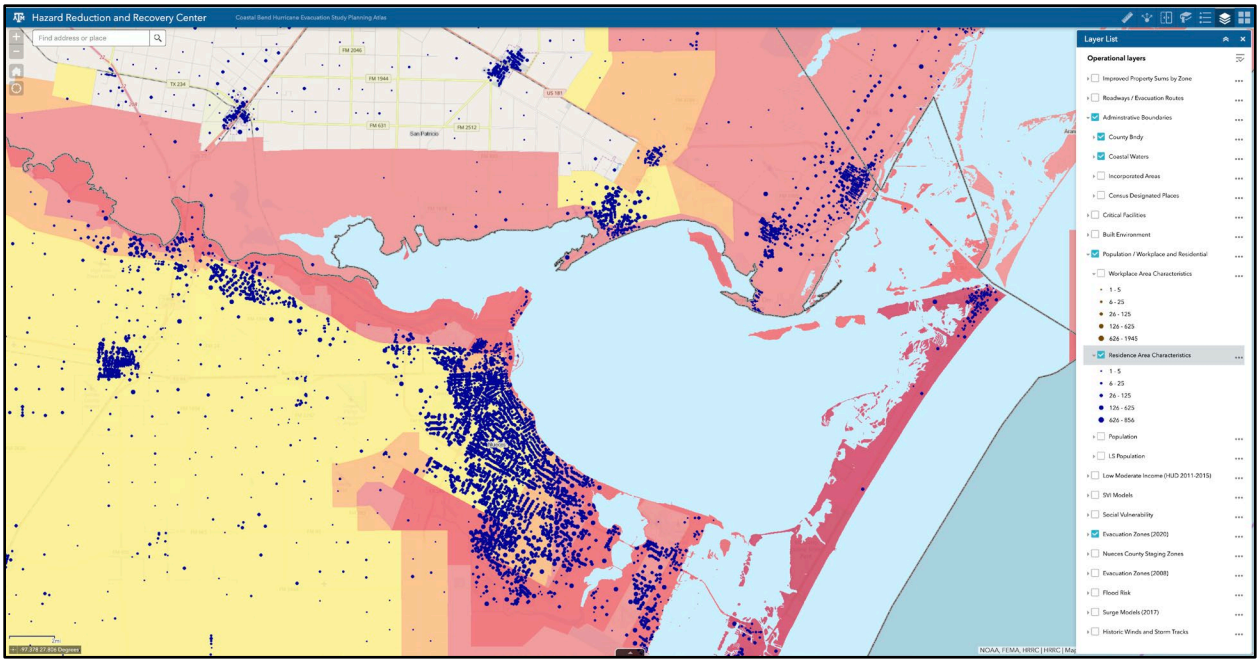

Figure 16. Employee Residential Locations and Hurricane Evacuation Zones.

A particularly useful feature of these data is that it is relatively easy to determine the numbers of jobs and residences within each of the evacuation zones. Table 7 presents data on the numbers of jobs within each zone for Coastal Bend counties. The second-to-last column in each panel presents the total number and percentage of all county jobs that fall within the evacuation zones. These data suggest that very nearly 100 percent of all jobs within Calhoun, Aransas, Kenedy, and Nueces Counties are located within evacuation zones. In Refugio County, 88 percent of its jobs are located in evacuation zones, and just over 62 percent of San Patricio County's jobs and nearly 43 percent of Kleberg County's jobs are located in evacuation zones. The only Coastal Bend county without substantial percentages of its economic activity—assessed in terms of jobs—not located in evacuation zones is Victoria County, where only 5.2 percent of its jobs are in evacuation zones.

Given the numbers of jobs located in evacuation zones in all but Victoria County, it will be important for emergency managers and county judges to work closely with the county business community to ensure coordination on job release should mandatory evacuations be called. If employees feel compelled to stay at their job locations because owners are hesitant to release them, evacuations can be delayed, particularly when they are occurring during the normal work week. A critical part of this coordination will be allowing workers and employees off to preparing their homes and households prior to evacuating. The literature suggests that preparation can delay response to evacuation orders (Peacock et al., 2007). So, making sure that employees are released from their job obligations so that they can prepare their homes, vehicles, and households before evacuating can facilitate timely response to evacuation orders.

Table 7. Jobs in Evacuation Zones in Coastal Bend Counties.

County	Zone A1	Zone A	Zone B	All Zones	County total
Calhoun	8,272	1,759	120	10,151	10,151
	81.5%	17.3%	1.2%	100.0%	100.0%
Victoria	n/a	1,647	252	1,899	36,289
		4.5%	0.7%	5.2%	100.0%

County	Zone A	Zone B	Zone C	All Zones	County total
Aransas	5,143	n/a	n/a	5,143	5,143
	100.0%			100.0%	100.0%
Refugio	285	1,553	134	1,972	2,242
	12.7%	69.3%	6.0%	88.0%	100.0%
San Patricio	7,081	722	3,060	10,863	17,451
	40.6%	4.1%	17.5%	62.2%	100.0%

County	Zone A	Zone B	Zone C	All Zones	County total
Kenedy	161	0	0	161	161
	100.0%	0.0%	0.0%	100.0%	100.0%
Kleberg	1,198	2,909	n/a	4,107	9,641
	12.4%	30.2%		42.6%	100.0%

County	Zone A1	Zone A2	Zone A3	Zone B	Zone C	All Zones	County total
Nueces	2,984	36,201	15,484	24,489	68,636	147,794	147,794
	2.0%	24.5%	10.5%	16.6%	46.4%	100.0%	100.0%

7. Estimated Vulnerable Property

The LODES data provide an understanding of the potential economic consequences of hurricane impact for the study area, at least with respect to employment and employee residences. Discussed in the previous section, it can be clearly seen that substantial percentages of jobs for most Coastal Bend counties are located in hurricane risk/evacuation zones. In this section, we now turn our attention to the vulnerability of the value of residential capital stock of Coastal Bend counties relative to hurricane risk/evacuation zones. The HES project team acquired comparable parcel data for Coastal Bend counties, allowing for a determination of the value of the residential structures/buildings and other improvements made on residential parcels located within each evacuation zone.[22]

Table 8 presents the data on the tax appraisal value for improvement (i.e., the value of what is built or located on the parcel, not the land value itself) built or located on all residential parcels for each of the Coastal Bend counties. Residential parcels were categories as single family, mobile home, and other types of residential structures (apartments, duplexes, etc.). These parcels are split into their associated evacuation zones for all counties.[23] To facilitate discussion, hurricane risk/evacuation zones presented in Table 8 have been shaded in a manner consistent with their shading on the HES *Planning Atlas*: Zone A is shaded in red, Zone B is in orange, Zone C is in yellow, and if counties have areas outside or not in hurricane risk/evacuation zones, these are shaded in blue.

In light of the findings in the first section of this report that examines county population distributions, particularly household distributions, across hurricane evacuation/risk zones, it is not surprising that a substantial percentage of the value of residential properties in many counties is also located in hurricane risk/evacuation zones. In fact, for many of these counties, substantial proportions are located in the highest-risk/evacuation zones. The most vulnerable is of course Aransas County, given that 100 percent of its 4.3 billion in residential property is in Zone A. Similarly, 99.5 percent of Calhoun County's 1.1 billion in residential property value is located in Zone A1 or A. Just over 64 percent of Refugio County's $268 million in residential property value is in Zone A. Just over half (51.3 percent) of Nueces County's $18.2 billion and San Patricio County's (50.5 percent) $3.2 billion in residential value are also located in their respective Zone A.

One of the major exceptions is again Victoria County, where over 97 percent of its residential valuation is outside hurricane risk zones. Kenedy County also has a relatively small proportion of its residential property at risk in its Zone A. Another exception appears to be Kleberg County; however, the data for this county are highly problematic in that over 5,000 single-family structures located in Zone B did not have improvement values. Therefore, the findings for Kleberg County should be ignored. On the whole, these numbers and percentages clearly suggest that the residential capital stock of most Coastal Bend counties is highly vulnerable to hurricane surge risk.

[22] The project team was not able to obtain tax assessment/parcel data from each county's appraisal office. Indeed, only a few appraisal offices were able to provide these data, and in many cases their formats and quality were highly problematic. However, partners at USACE were able to provide these data for most counties.

[23] Some properties were split by evacuation zone. In the event this occurred, building footprint data were used to place the improvement values into the zone in which the structures were located.

Table 8. Tax Appraisal Values of Coastal Bend Residential Parcels by County and Hurricane Risk/Evacuation Zones.

County	EvacZone	Single Family Residences	Mobile Home	Other Residential	Total by Zone	% of County value
Aransas	A	$1,739,186,041	$174,305,126	$1,197,900,954	$4,309,293,075	100.0%
	County Totals	**$1,739,186,041**	**$174,305,126**	**$1,197,900,954**	**$4,309,293,075**	**100.0%**
Calhoun	A1	$853,125,552	$37,330,873	$44,797,309	$980,051,043	88.0%
	A	$112,265,463	$5,642,941	$5,247,009	$128,402,422	11.5%
	B	$4,096,970	$800,450	$134,660	$5,166,740	0.5%
	County Totals	**$969,487,985**	**$43,774,264**	**$50,178,978**	**$1,113,620,205**	**100.0%**
Kenedy	A	$0	$0	$111,470	$222,940	1.3%
	C	$4,685,689	$130,106	$5,101,410	$15,018,615	86.2%
	Outside	$332,780	$0	$923,420	$2,179,620	12.5%
	County Totals	**$5,018,469**	**$130,106**	**$6,136,300**	**$17,421,175**	**100.0%**
Kleberg	A	$33,425,556	$3,039,800	$0	$36,465,356	13.6%
	B	NA	$4,648,957	$3,413,492	$11,475,941	4.3%
	Outside	$194,761,329	$4,777,830	$10,233,543	$220,006,245	82.1%
	County Totals	**$228,186,885**	**$12,466,587**	**$13,647,035**	**$285,368,717**	**100.0%**
Nueces	A1	$2,622,523,656	$97,338,633	$486,315,135	$3,692,492,559	20.3%
	A2	$3,562,196,496	$22,506,286	$159,756,657	$3,904,216,096	21.4%
	A3	$1,627,648,586	$15,094,861	$56,039,390	$1,754,822,227	9.6%
	B	$2,869,945,175	$25,040,420	$89,335,537	$3,073,656,669	16.9%
	C	$4,744,527,399	$845,122,320	$103,026,069	$5,795,701,857	31.8%
	County Totals	**$15,426,841,312**	**$1,005,102,520**	**$894,472,788**	**$18,220,889,408**	**100.0%**
Refugio	A	$143,204,340	$21,297,610	$3,738,880	$171,979,710	64.1%
	B	$28,434,460	$4,653,280	$546,500	$34,180,740	12.7%
	C	$0	$853,040	$0	$853,040	0.3%
	Outside	$53,461,260	$5,699,220	$1,044,560	$61,249,600	22.8%
	County Totals	**$225,100,060**	**$32,503,150**	**$5,329,940**	**$268,263,090**	**100.0%**
San Patricio	A	$1,537,905,328	$21,727,327	$21,307,553	$1,602,247,761	50.5%
	B	$53,788,753	$5,201,457	$329,592	$59,649,394	1.9%
	C	$724,429,318	$934,665	$3,605,625	$732,575,233	23.1%
	Outside	$708,699,867	$60,197,454	$4,657,182	$778,211,685	24.5%
	County Totals	**$3,024,823,266**	**$88,060,903**	**$29,899,952**	**$3,172,684,073**	**100.0%**
Victoria	A	$13,114,767	$1,406,821	$242,790	$15,007,168	0.4%
	B	$80,549,044	$4,745,949	$1,627,360	$88,549,713	2.4%
	Outside	$3,334,316,567	$64,863,299	$102,453,645	$3,604,087,156	97.2%
	County Totals	**$3,427,980,378**	**$159,076,972**	**$104,323,795**	**$3,707,644,037**	**100.0%**

8. Social Vulnerability Mapping Layers

As mentioned previously, the HES team has also created a number of ***social vulnerability layers*** to help local emergency management and stakeholders when planning for evacuation as well as overall emergency response, disaster planning, and long-term recovery planning. The scientific literature is quite clear that often the ability of individuals and households to marshal economic and capital resources, along with the ability to activate their kinship and friendship networks, shapes their abilities to prepare for, respond to, and recover from disasters (Van Zandt et al., 2012; Peacock et al., 2012; Masterson et al., 2014).

Figure 17 captures this perspective. Due to the nature of social processes and structures, an individual's or household's socioeconomic, demographic, and cultural characteristics related to factors such as race/ethnicity, gender, education, wealth, and income can lead to very different levels of capacity; the abilities to access, interpret, and understand information; and access to power and resources. In turn, this generates disparities in disaster impacts, evacuation, response, restoration, and recovery. In other words, in addition to physical vulnerabilities, social vulnerabilities have consequences for evacuation, response, restoration, and recovery.

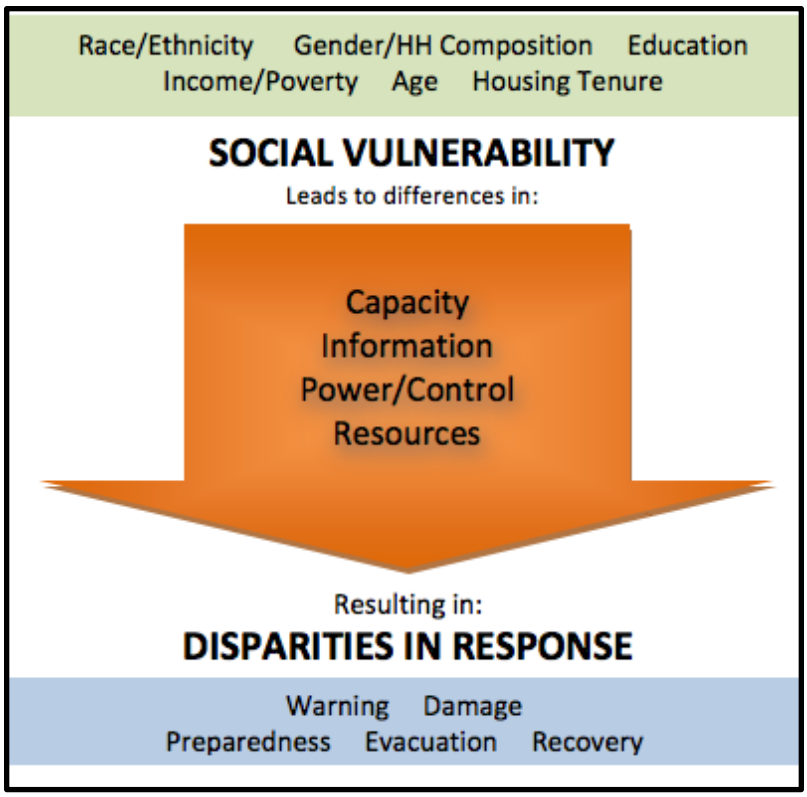

Figure 17. Social Vulnerability Shaping Response and Recovery Outcomes.

In this context, it is important to realize and understand the social, economic, and demographic characteristics of households and individuals that have consequences for evacuation, responses, mitigation, and recovery. It is equally important to identify concentrations of households with these characteristics, relative to hazard exposure, to better plan for and respond to disaster threats such as hurricanes. For example, the previous sections discuss approaches for identifying areas with high concentrations of households without their own vehicle. Not surprisingly, these are often households

with low income, lower levels of education, and poverty. These latter characteristics also have consequences for preparation time, the ability to prepare homes for potential impacts, etc. Similarly, areas with higher concentration of households headed by elderly individuals are identified because they are likely to delay preparation, have difficulties evacuating, etc.

The key here is to combine knowledge of factors shaping social vulnerability (socioeconomic, demographic, educational, cultural, etc.) with mapping tools to identify areas within the communities with high concentrations of households with these attributes so planners can better address these problems and issues as part of evacuation, response, mitigation, and recovery plans. To make this possible, the project team created a number of data layers within the *Planning Atlas* website that can be used to better locate high concentrations of populations with social and economic characteristics that can result in higher levels of vulnerability to hurricanes and other disaster agents.

Table 9 displays 17 different data layers, along with their names and a brief description of each layer, which can be used to identify individuals, households, and neighborhoods that are likely to be more socially vulnerable to various activities associated with disaster preparation, response, and recovery according to the literature. These data layers have been clustered into different conceptual dimensions or clusters, suggesting various areas of disaster response difficulties or needs. For example, single-parent households with children and concentrations of children below five are likely to have ***child care needs***. Similarly, areas with higher concentrations of elderly households and elderly households in poverty are likely to have elevated ***elderly care needs*** related to all kinds of issues such as evacuation preparation, evacuation, health care issues in the aftermath of a disaster because of power failures, medical needs, etc.

Table 9. Social Vulnerability Data Layers.

1st Order SV Indicators	Conceptual Grouping
1) Single-Parent Household with Children 2) Child Population under 5 Years	Child Care Needs
3) Elderly Households 4) Elderly Households in Poverty	Elderly Care Needs
5) Public Transportation Dependent Households 6) Households with No Vehicle Available	Transportation Needs
7) Vacant Housing Units 8) Renter Households 9) Population in Group Quarters 10) Housing Units Built before 1990 11) Mobile Home Households	Temporary Shelter Needs and Housing Recovery Needs
12) Non-White Population 13) Households in Poverty 14) Housing Units with No Telephone Service Available 15) Less than High School Graduate Population 25+ Years 16) Unemployed Population in Labor Force 17) Population Speaking English Not Well or Not at All	Civic Capacity Needs

Transportation related needs are captured by two indicators:

- Households without their own private vehicle (discussed previously).
- Households dependent on some form of public transportation to get to their work.

The next cluster of indicators are often associated with ***temporary shelter needs*** and ***housing recovery needs.*** These indicators include:

- Renter households (renters are often displaced after a disaster, and rental housing is often unavailable after a disaster and slow to come back on line).
- Population in group quarters (nursing homes, dorms, etc., which are often displaced and can be associated with major problems in evacuations and early response and recovery).
- Housing units built before 1999 (older housing, often built under older, less-stringent building codes, which can often have maintenance issues).
- Mobile homes (unsafe in wind storms of any kind and often damaged by disasters because of less-stringent building materials and weaker construction) (data from the U.S. Census).

Finally, a set of indicators is for areas with high concentrations of households in poverty, households without phone service, non-white populations, adults lacking high school diplomas, unemployed, and adults with low or no English skills. All of these indicators capture areas with ***low civic capacity.*** These are areas that experience multiple difficulties, not only in evacuating but also in preparing and responding to disaster risks and warnings, and coping with the aftermath of a disasters.

Using the SV data layers, each of these indictors is based on ACS 5-year estimate data at the census block group level of aggregation. In many respects, the block group level is ideal, particularly in more urban areas, since these areal units often capture recognizable neighborhoods or parts of neighborhoods. However, they can be problematic in more rural areas, where the spatial areas associated with block groups can be rather large. Additionally, they can even be difficult to use in suburban areas, particularly when there are mixed-use areas with only small areas actually devoted to residential housing. To enhance the utility of these data, the *Planning Atlas* presents these data in a more conventional form, using actual block group boundaries and modeled SV data. The block group information is filtered using finer-resolution population data to better capture areas within block group boundaries with higher concentrations of people. Examples of these two SV mapping approaches are shown in Figure 5 and Figure 7, displaying areas with higher concentrations of households without vehicles and elderly households, respectively.

In all cases, these block group social vulnerability indicators (SVIs) have been compared across all block groups ***within each county*** and then shaded from darker to lighter colors, where the darker the color, the higher the concentration of households, individuals, or housing units across all block groups within the county. In other words, the color schemes from low to high social vulnerability are all county specific and are ***not*** based on the entire Coastal Bend area. This scheme should therefore allow for planners within a county to identify concentrations or hot spots of highly vulnerable populations within each county where additional attention—through policies, programs, or actions—should be concentrated to ensure the development of effective hurricane planning or other forms of disaster/natural disaster planning within each county. Indeed, these mapping tools are not just important for evacuation planning; they can be used for all forms of community resiliency planning activities.

As an example of using these data, Figure 18 displays block group concentrations of individuals 16 years or older that do not speak English well or at all. The display here includes parts of Nueces, San Patricio, and Aransas Counties. The darker the color, the higher the concentrations of individuals with these characteristics. Additionally, this color scheme is relative to other block groups ***within the county***. Figure 19 displays the modeled SV data, which attempts to better capture smaller areas with higher concentrations of individuals not speaking English well or at all. At this scale, it is difficult to see the concentrations although some appear quite clearly in Corpus Christi, Ingleside, and Portland. To truly see the level of resolution, Figure 20 displays the same data but zoomed in to Ingleside and Aransas Pass.

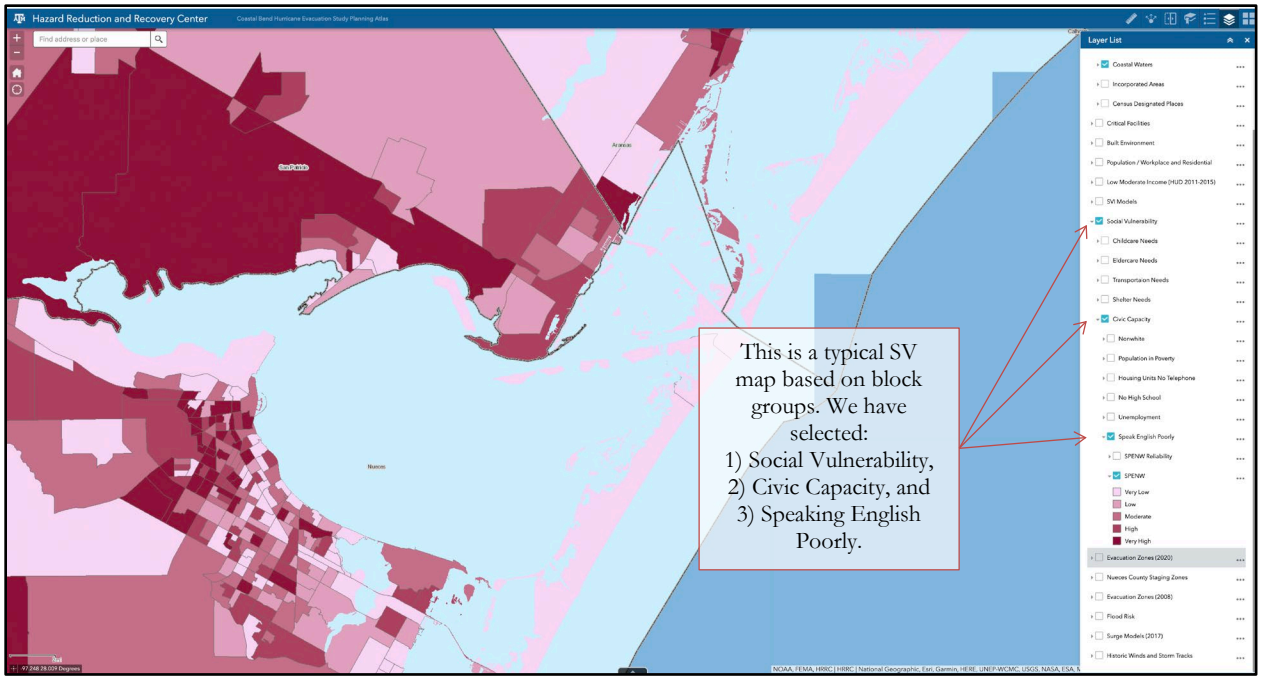

Figure 18. Individuals over 16 Not Speaking English Well or At All.

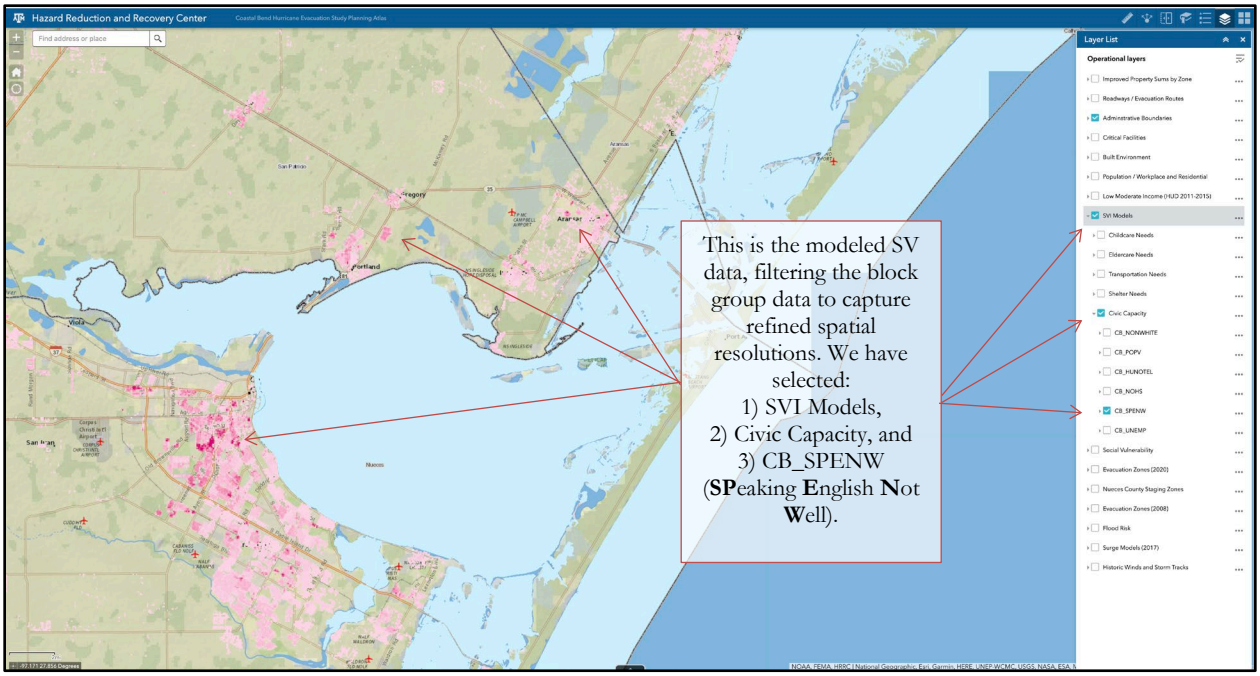

Figure 19. Modeled SVI Data on Individuals Not Speaking English Well or at All.

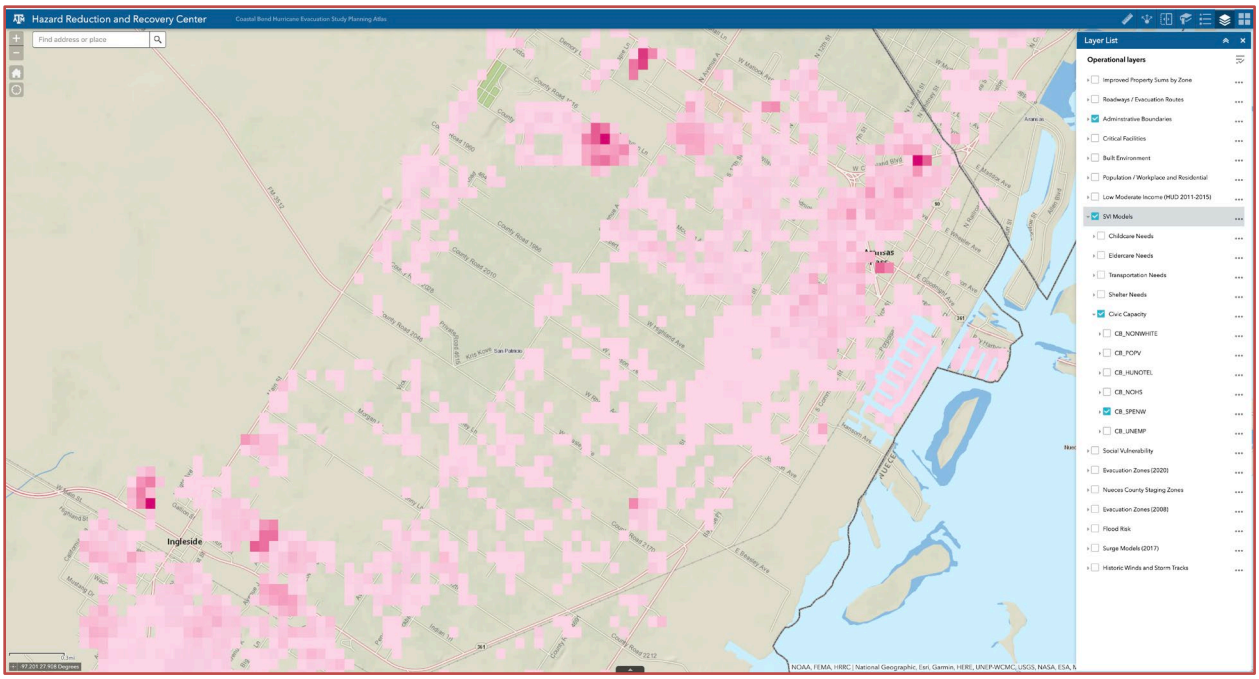

Figure 20. Modeled SVI Data on Individuals Not Speaking English Well or at All in Aransas Pass and Ingleside Area.

So, the traditional SV mapping tool gives a rather clear assessment of block groups with relatively higher (or lower) concentrations of individuals, households, or housing units with specific characteristics. The modeled SVI data provide a potential opportunity for gaining additional information about likely concentrations at a finer resolution. However, regardless of the tool

employed, these are but approximations of where one might target areas for further investigation and where to undertake education, outreach, and other programs or policies.

These are first steps. The critical steps require outreach and local knowledge—getting out into the community and working with local groups, organizations, churches, and neighborhood community groups to better understand what can be done to enhance evacuation planning and other planning activities. With these data, planners can understand the potential social vulnerabilities evident in the community; working with groups and individuals in these areas, planners can better plan and solve potential problems before it is too late.

Summary and Conclusion

This report describes a vulnerability analysis using the newly developed evacuation zones and discusses many of the new and improved data layers developed to undertake this analysis. Furthermore, the report describes many of the data layers that have been incorporated into the Coastal Bend HES *Planning Atlas* (https://texasatlas.arch.tamu.edu/fv/cb_hes). This analysis makes it clear that substantial proportions of Coastal Bend populations, economic activities, and physical capital are located within the new/updated hurricane risk/evacuation zones and are therefore at considerable hurricane risk when it comes to surge. Furthermore, when focus is on the most vulnerable types of structures, such as mobile homes, or vulnerable individuals and households, such as those without private vehicles or living at or below the poverty level, again substantial proportions of these structures and populations are located in hurricane risk/evacuation zones.

Consequently, there is much to be concerned about when it comes to hurricane evacuation in particular and broad-based hazard/disaster planning in general. In a very real sense, the analyses presented in this report are just the beginning. This is why the project team created the *Planning Atlas* for the Coastal Bend. The project team encourages the local participants in the HES planning process to work with and use this website to conduct their own investigations of the region's vulnerabilities and strengths. Indeed, these data and the *Planning Atlas* website should be shared with other interested stakeholders and groups throughout the region.

Local participants throughout the entire HES process have shown dedication, local knowledge, and commitment to making their community and their region safe. The project team sincerely hope that the *Planning Atlas* website and the data they have compiled and developed will help community leaders in their endeavors to make their homes and community safe in the future.

References

Lindell, M. K., Kang, J. E., and Prater, C. (2011). The Logistics of Household Hurricane Evacuation. *Natural Hazards,* 58(3), 1093-1109.

Lindell, M. K., Murry-Tuite, P., Wolshon, B., and Baker, E. J. (2019). *Large Scale Evacuation: The Analysis, Modeling, and Management of Emergency Relocation from Hazardous Areas*. New York: Routledge.

Masterson, J. H., Peacock, W. G., Van Zandt, S., Grover, H., Field Schwarz, L., and Cooper, J., Jr. (2014). *Planning for Community Resilience: A Handbook for Reducing Vulnerability to Disasters*. Washington, D.C.: Island Press.

Maghelal, P., Li, X., and Peacock, W. G. (2017). Highway Congestion during Evacuation: Examining the Household's Choice of Number of Vehicles to Evacuate. *Natural Hazards,* 87, 1399-1411. DOI: 10.1007/s11069-017-2823-5.

Maghelal, P., Peacock, W. G., and Li, X. (2017). Evacuating Together or Separately: Factors Influencing Split Evacuations prior to Hurricane Rita. *Natural Hazards Review,* 18(2). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000226.

Peacock, W. G., Van Zandt, S., Henry, D., Grover, H., and Highfield, W. (2012). Social Vulnerability and Hurricane Ike: Using Social Vulnerability Mapping to Enhance Coastal Community Resiliency in Texas. Chapter 6, pp. 66–81, in *Lessons from Hurricane Ike.* Edited by P. B. Bedient. College Station, Texas: Texas A&M University Press.

Peacock, W. G., Maghelal, P., Lindell, M. K., and Prater, C. S. (2007). *Hurricane Rita Behavioral Survey Final Report.* College Station, Texas: Hazard Reduction and Recovery Center, Texas A&M University. This also appeared as a chapter (pp. 3–74) of a monograph titled *Disaster Preparedness in Texas*, which is available at http://san-antonio.tamu.edu/disasterstudy/.

Van Zandt, S., Peacock, W. G., Henry, D., Grover, H., Highfield, W., and Brody, S. (2012). Mapping Social Vulnerability to Enhance Housing and Neighborhood Resilience. *Housing Policy Debate*, 22(1), 29-55.

Wu, H. C., Lindell, M. K. & Prater, C.S. (2012). Logistics of hurricane evacuation in Hurricanes Katrina and Rita. *Transportation Research Part F: Traffic Psychology and Behaviour, 15,* 445-461.