Behavioral Study, Valley Hurricane Evacuation Study, Willacy, Cameron, and Hidalgo Counties, Texas

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30 September 2013

EXECUTIVE SUMMARY

The Texas A&M University Hazard Reduction & Recovery Center conducted a mail survey of the general population of the Valley Study Area (VSA) counties—Cameron, Willacy, and Hidlago—and, in conjunction with the Colonias Program, conducted personal interviews with the population of selected colonias in those counties. In Cameron and Willacy counties, the sample was stratified by the hurricane risk areas that are currently in effect. That is, questionnaires were sent to residents of Risk Areas 1-5 as well as to the remainder of the county that is inland from the hurricane risk areas. In Hidalgo County, the sample was stratified by location east or west of IH-69/US-281 (Hidalgo East and Hidalgo West, respectively) or in the 500-year floodplain (regardless of their location in either Hidalgo East or Hidalgo West. The response rate for the mail survey was 23.3% and the response rate for the personal interviews was 50.4%--yielding an overall sample size of 481.

The survey data indicate that 39% of the VSA population lacks hurricane experience, 18% has experienced a hurricane and evacuated, and 44% experienced a hurricane but did not evacuate. Most people expect to obtain most of their hurricane information from National Hurricane Center watches and warnings, local TV and radio stations and, to decreasing extents, from national TV networks, peers, local officials, local newspapers, the Internet, and social media. As one might expect, the percentage of residents expecting to evacuate increases with storm intensity. However, the percentage expecting to evacuate for a Tropical Storm is surprisingly high, with some people from Risk Area 5 and even inland areas of Cameron and Willacy counties expecting to evacuate for this category of storm. Such *shadow evacuation* (evacuation from areas that are unlikely to be advised to do so) increases with hurricane intensity. Conversely, there is likely to be *incomplete compliance* (people failing to evacuate from areas that would be advised to do so) at all levels of storm intensity—although the level of incomplete compliance is likely to be less than the level of shadow evacuation. The data also indicate that there is likely to be a very high level of shadow evacuation from Hidalgo County for all storm categories, with the evacuation rates significantly higher in Hidalgo East than in Hidalgo West only for the lower storm categories (Tropical Storm-Category 3). Shadow evacuation from Hidalgo could be extremely high for Category 4 and 5 hurricanes.

VSA residents expressed only moderate concern about six of the seven listed evacuation inhibitors—protecting their property from a storm, traffic jams, evacuation expenses, looting risks, traffic accidents, and income loss. They expressed minimal concern about security checkpoints. These data indicate that concerns about these issues are unlikely to have a significant adverse effect on people's willingness to evacuate. However, about 17% of VSA residents reported having household members needing special medical assistance to evacuate, which could inhibit evacuation rates unless assistance is available to address this impediment. In addition, 55% of the urban respondents and 40% of the colonias residents reported having pets

needing to be evacuated along with household members. This could depress evacuation rates for people needing to stay in commercial facilities or public shelters if they are unaware of any provisions for sheltering pets. Only a small percentage of respondents reported lacking a personal vehicle for evacuation and most of them (78%) plan to rely on rides with peers (friends, relatives, neighbors, or coworkers), which will reduce the traffic load on the evacuation routes although this effect will be slight. Nonetheless, there will be a significant number of households expecting to take public transportation so emergency managers and transit officials need to address this issue in their hurricane plans.

Consistent with previous studies of hurricane evacuations, VSA residents expect to take approximately 1.6 vehicle equivalents (cars, trucks, trailers, and recreational vehicles) when they evacuate. Thus, the vehicular demand will be 60% larger than the number of evacuating households. When they leave, most VSA residents expect to travel to other areas of South Texas, especially San Antonio (47%) and Laredo (10%). Approximately one quarter expect to travel to Houston (10%), Austin (10%), and Dallas (4%) and only a few expect to stay in inland areas of VSA such as McAllen (5%), Brownsville (1%), Edinburg (3%), and Harlingen (1%). To reach their destinations, evacuees expect to rely primarily on US-281 (44%), US-77 (33%), and US-83 (31%). (The total percentage expecting to rely on all highways is greater than 100% because some respondents reported multiple highways.) When evacuees reach their destinations, about 50% expect to stay with peers (friends and relatives), 30% expect to stay in commercial facilities (hotels and motels) and about 10% expect to stay in public shelters. These estimates are consistent with previous studies on hurricane evacuation.

VSA resident have strong expectations that, within the next five years, hurricanes will cause disruption to services such as electric power and communications. They have moderate expectations of damage within their communities, damage to their own homes from wind and flooding, disruption to their jobs, and casualties in their communities. They have relatively weak expectations of casualties in their households and damage from storm surge, although the latter expectations are highly variable because only some of the residents of Cameron and Willacy counties—and none of those in Hidalgo County—would be vulnerable to surge.

On average, relatively few VSA residents report having elevated their homes above the base flood (38%), wet floodproofed their homes (27%), or dry floodproofed them (23%). Thus, many VSA residents will need to evacuate if storm surge or inland flooding strikes their neighborhoods. Moreover, VSA residents reported having performed only 6.0 of ten disaster preparedness measures, with flashlights (87%), battery powered radios (78%), and stored water (78%) being most the common items and gas powered electric generators being the least common (25%). Consequently, VSA residents are only moderately prepared to respond to a hurricane.

Most (90%) VSA residents who live in hurricane risk areas accurately reported that they did, indeed, live in a hurricane risk area, but over half (53%) of those who live in inland areas inaccurately reported that they lived in a hurricane risk area. Given the substantial proportion of the VSA population that lives outside the hurricane risk areas, this indicates a potential for a very substantial shadow evacuation. Thus, emergency managers and other local officials will need to be very active in publicizing hurricane risk area boundaries throughout the hurricane season and, especially, as a hurricane approaches the VSA. Overall, VSA residents tended to think of themselves as moderately susceptible to wind risk (3.1 on a 1-5 scale), slightly less susceptible to inland flood risk (2.8), and least susceptible to surge risk (2.3).

The *Analysis* section of this report combines the data from the Urban and Colonias surveys with GIS analyses of census data to generate tables that forecast the numbers of evacuees and evacuating vehicles (Tables 10a-10c), expected evacuation destinations (Table 11), expected evacuation routes (Table 12), and expected number of commercial rooms and public shelter beds in VSA needed to accommodate evacuees (Table 13). This section also reports analyses of VSA residents' hurricane evacuation experience by evacuation expectations (Tables 14a-14c) and the significant factors influencing the population's decisions to evacuate or stay (Table 15). Finally, this section reports the traffic loading functions from Hurricanes Lili, Katrina, Rita (GSA only) and Ike to provide local emergency managers and other officials with an understanding of the differences across hurricanes in the rates at which evacuees enter the evacuation route system.

INTRODUCTION

A timely and effective evacuation of threatened areas of the Texas Gulf Coast requires accurate information about how risk area residents will respond to a hurricane evacuation warning. One important source of such information is the research on people's responses in previous emergencies. Dozens of studies have examined the processes by which public officials make decisions to recommend evacuation and threatened populations respond to warnings. The results of many such studies have been summarized by Mileti, Drabek and Haas (1975), Drabek (1986), Lindell and Perry (1992, 2004, 2012), Sorensen (2000), Tierney, Lindell and Perry (2001), and Lindell (2012).

Baker (1991) and Dash and Gladwin (2007) have summarized research on hurricane evacuation decision making. More recently, Huang et al. (2012) and Stein et al. (2010) have conducted studies on hurricane evacuation decision making and Lindell et al. (2011), Wu et al. (2012), Siebeneck et al. (2013), and Lin et al. (2013) have conducted research on the logistics of hurricane evacuation—the activities that take place between a household's evacuation decision and their return home. In addition, Lindell and Prater (2007), Lindell (2008), Murray-Tuite and Wolshon (2013), Trainor et al. (2013) and Lindell (2013) have proposed models that integrate social science and engineering approaches to hurricane evacuation planning and modeling.

This previous research has identified many general principles about people's behavior in disasters, but it cannot answer all of the questions that arise in connection with developing local and regional evacuation plans. Specifically, people's behavior is affected by their previous experience, local conditions, and the circumstances that they encounter at the time of the event. For example, researchers have found that evacuation is affected by households' perceptions of warning sources, interpretation of warning messages, access to evacuation vehicles, concerns about the safety of persons and property, economic assets, and knowledge of a safe route to an acceptable destination (Lindell & Perry, 2012). Consequently, location-specific surveys are needed to assess these conditions and people's expectations regarding what they will do if a hurricane is predicted to strike their area.

To better understand how people are likely to respond to a hurricane approaching the Valley Study Area (VSA), the U.S. Army Corps of Engineers has established five objectives for a hurricane behavioral survey. Objective 1 is to determine the number of potential evacuees and evacuating vehicles within the three county study area under various Tropical Storm/hurricane scenarios (e.g. Tropical Storm and Category 1-5 hurricanes). Objective 2 is to identify the popularity of different evacuee destinations and the types of accommodations evacuees plan to seek while evacuated. Objective 3 is to determine the general level of awareness, hurricane experience, and evacuation experience of the vulnerable population and how this experience may affect the decision to evacuate. Objective 4 is to determine the significant factors influencing the population's decisions to evacuate or stay (e.g., local officials, personal resources, border security checkpoints, social influences, media, job, etc.). Objective 5 is to identify the evacuation timeframe and how the threatened population will evacuate in response to official evacuation orders as well as various defined forecast storm conditions such as category of hurricane and potential flooding).

METHOD

Sampling Procedure

The Texas A&M University Hazard Reduction & Recovery Center (HRRC) conducted two surveys in the three VSA counties—Cameron (total population = 406,220; colonias population = 46,842; percentage in colonias = 11.5%), Willacy (total population 22,134; colonias population = 3,465; percentage in colonias = 15.7%), and Hidalgo (total population 774,769; colonias population = 138,458; percentage in colonias = 17.9%) counties. The first survey was a mail survey of the general population of incorporated areas of the three counties. This survey, which was conducted during November and December of 2012, involved sending both an English and a Spanish version of the questionnaire to each of the selected households. The second survey, which focused on the colonias, involved personal contact with sample members—either as personal questionnaire deliveries (for those sample members that the interviewers judged to be literate in either English or Spanish) or personal interviews (for those sample members that the interviewers judged to have questionable literacy in either English or Spanish). The personal contact survey was conducted between March and May 2013.

Mail survey. The sampling procedure used Geographical Information System analyses to identify the ZIP codes for hurricane Risk Areas 1-5 so the Cameron and Willacy county samples could be stratified with respect to hurricane surge exposure (Figure 1 and Figure 2)[1]. In each of these counties, Risk Areas 1 and 2 were combined, as were Risk Areas 4 and 5. This produced four strata, Risk Areas 1&2, Risk Area 3, Risk Areas 4&5, and the Inland Area (the remainder of the county). However, the significantly different sizes of the populations in Cameron (406,220) and Willacy (22,134) counties dictated allocating a larger sample size to Cameron County so its margin of error would be smaller than that for Willacy County.

There were 50 households selected from each of the four strata in Willacy County, for a total of 200 households. In the event of a 50% response rate, the Willacy County 95% margin of error would be 9.8%. Consequently, any questionnaire item with which 50% of the respondents agree would have a 95% margin of error that ranges approximately 40-60%. For example, if 50% of

[1] This report is based upon the VSA risk area maps that were available during the 2013 hurricane season. The evacuation analyses will be revised when Cameron and Willacy counties have officially adopted their new evacuation zone maps.

the respondents from Willacy County said they would evacuate for a Category 3 hurricane, this would lead to a lower bound estimate of 22,134 x 40% = 8854 evacuees and an upper bound estimate of 22,134 x 60% = 13,280 evacuees. This is a plausible range of 4,427 evacuees.

There were 150 households selected from each of the four strata in Cameron County for a total of 600 households. Examining the same conditions as in Willacy County (50% response rate), then the 95% margin of error would be 5.7%. Consequently, any questionnaire item with which 50% of the respondents agree would have a 95% margin of error that ranges approximately 44-56%. For example, if 50% of the respondents from Cameron County say they would evacuate for a Category 3 hurricane, this would lead to a lower bound estimate of 406,220 x 44% = 178,736 evacuees and an upper bound estimate of 406,220 x 56% = 227,483 evacuees—a range of 48,746 evacuees. Thus, the range of plausible estimates for Cameron County would be about 11 times as large as the range for Willacy County. However, the range of plausible estimates for Cameron County would be about 18 times as large as the range for Willacy County if there were equal sample sizes in both counties. That is, the larger sample size in Cameron County would decrease the difference in the range of plausible estimates even though it would not eliminate that difference. The size of the range of plausible estimates for Cameron County is particularly important because most of the evacuees of that county are likely to travel through Willacy County or into or through Hidalgo County to find a safe location to stay until returning home. Thus, substantial uncertainty about the range of plausible estimates for Cameron County could have a significant effect on planning for evacuation traffic management and provision of beds in public shelters. Unfortunately, given the limitations on total sample size that are imposed by constraints on the cost of sending out questionnaires, it was not possible to further reduce the range of plausible estimates by a significant amount without substantially reducing the size of the Hidalgo County sample or completely eliminating the Willacy County sample. Neither of these alternatives was acceptable, so no further changes were made to the size of the Cameron County sample.

Hidalgo (population 774,769) has no hurricane risk areas because it is so far inland. However, there is a possibility that some households in the eastern part this county would evacuate in response to a *perceived* hurricane threat and would do so at higher rates than households in the western part of the county. Indeed, evacuation from inland areas was a major problem in the 2005 Hurricane Rita evacuation, where three studies (Stein et al., 2010; Lindell & Prater, 2008; Peacock et al., 2006) indicate that approximately 50% of the population of Harris County evacuated even though only about 15% of the county's population was located in hurricane risk areas. Moreover, there are some portions of Hidalgo County that are located within the 500-year floodplain and residents of these areas might evacuate due to concerns about inland flooding such as occurred in Harris County during Tropical Storm Allison in 2001. Consequently, the county was divided into three strata—Hidalgo East, Hidalgo West, and Hidalgo 500-year floodplain—with 150 households selected from each stratum (Figure 3). We defined Hidalgo

Figure 1: Urban Areas Overlaid with Hurricane Risk Areas

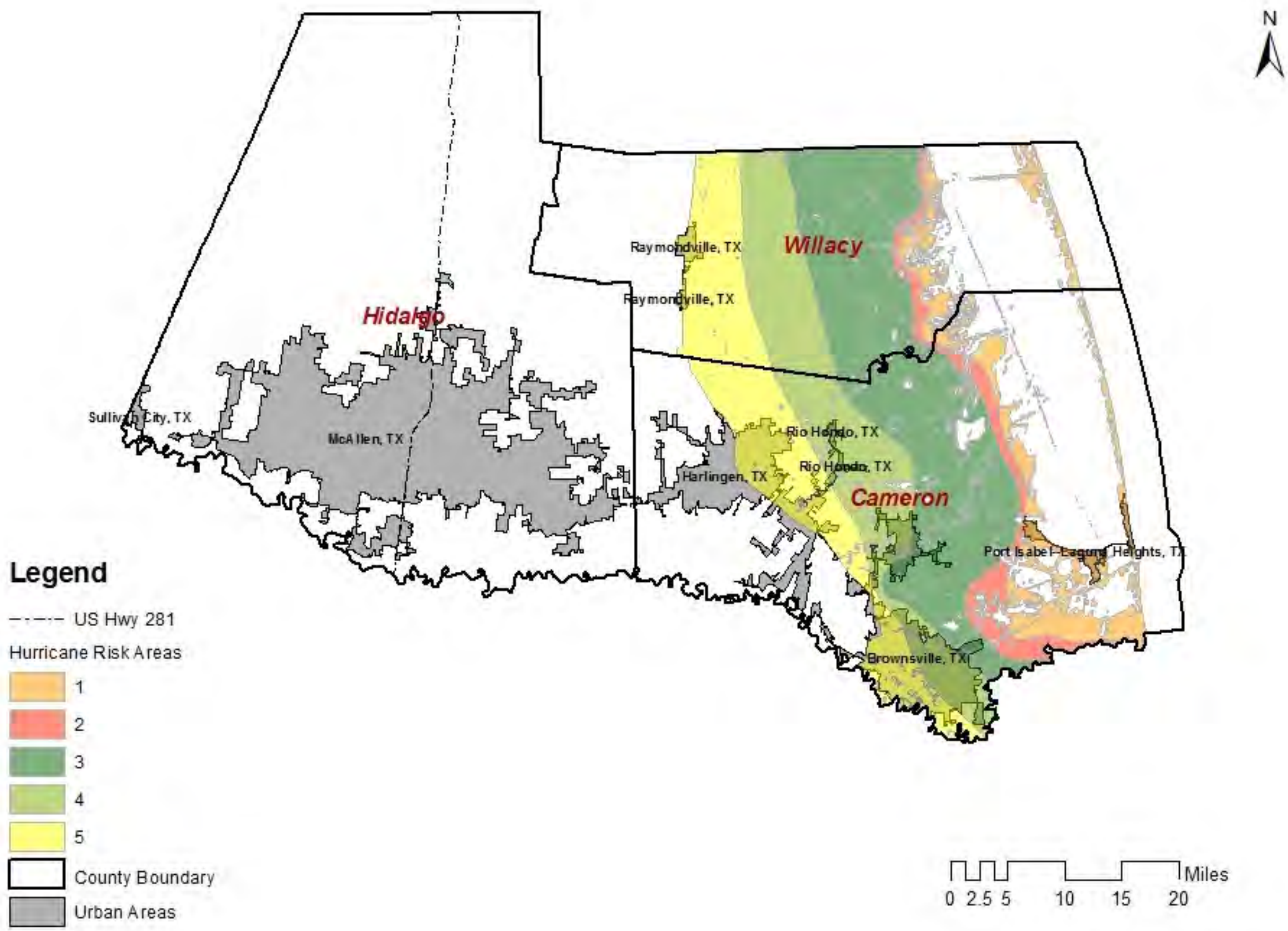


Figure 2: Urban Areas in Zip Codes Overlaid with Hurricane Risk Areas

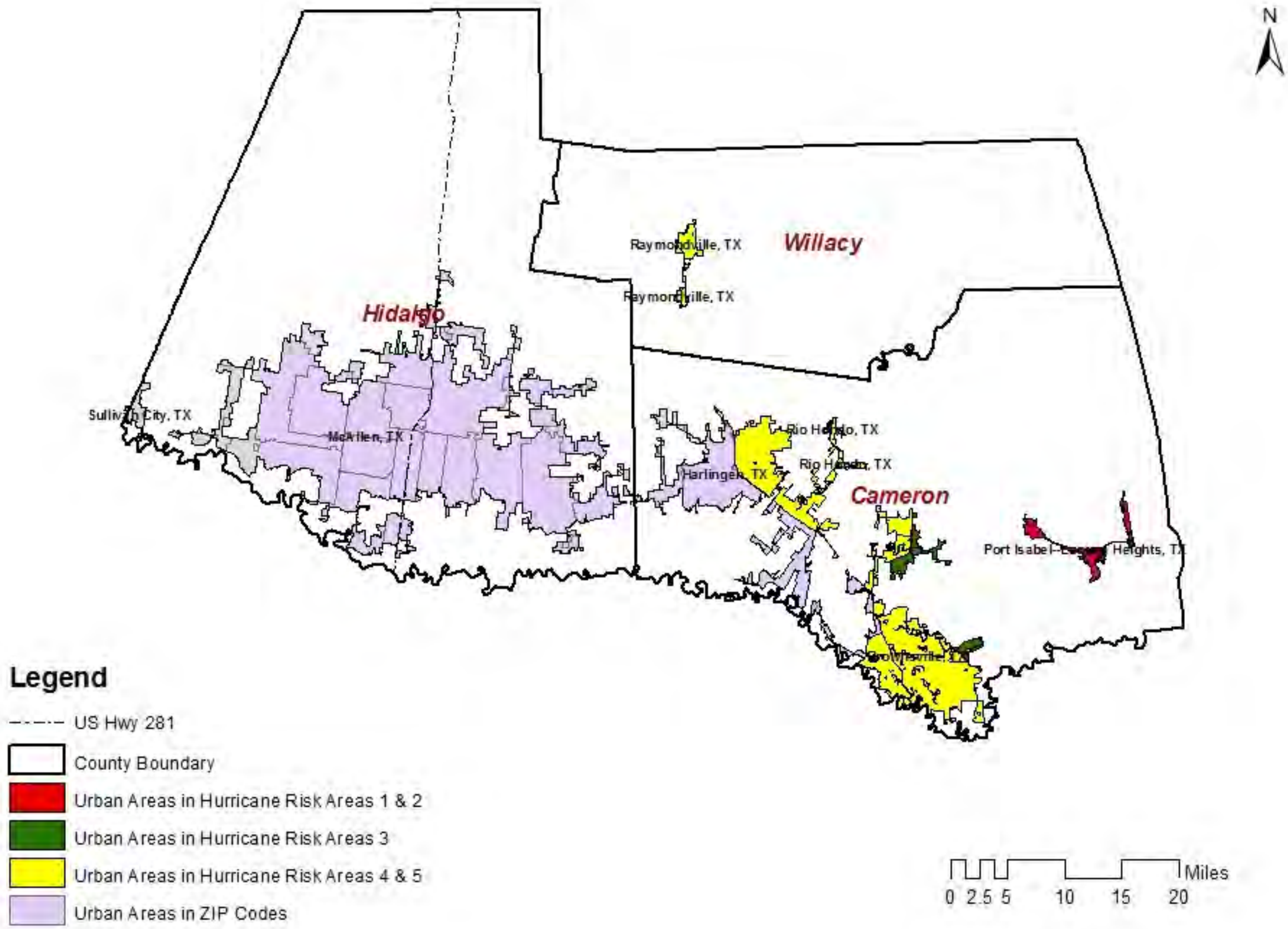


Figure 3: Urban Areas in Zip Codes Overlaid with 500-year Floodplains

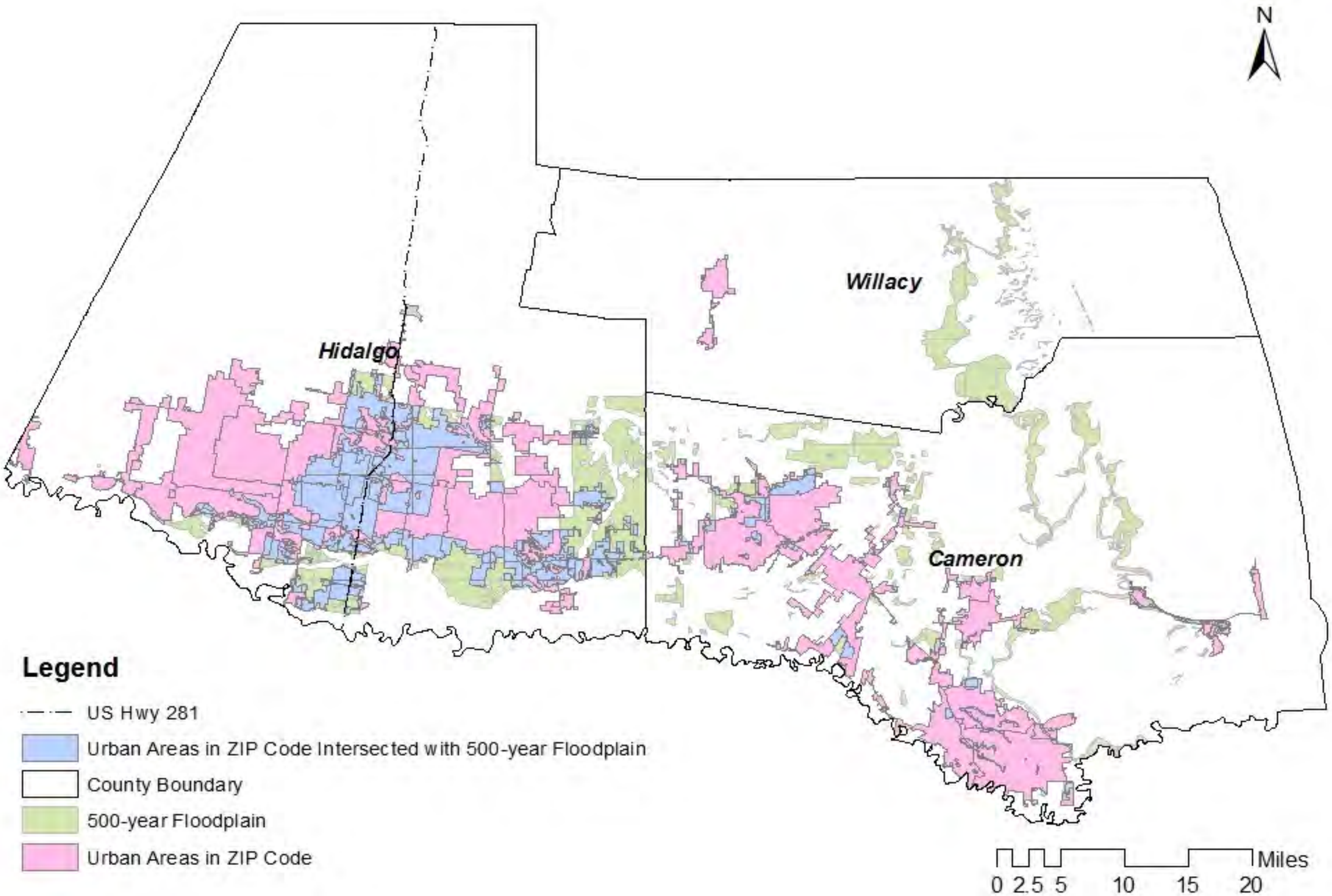
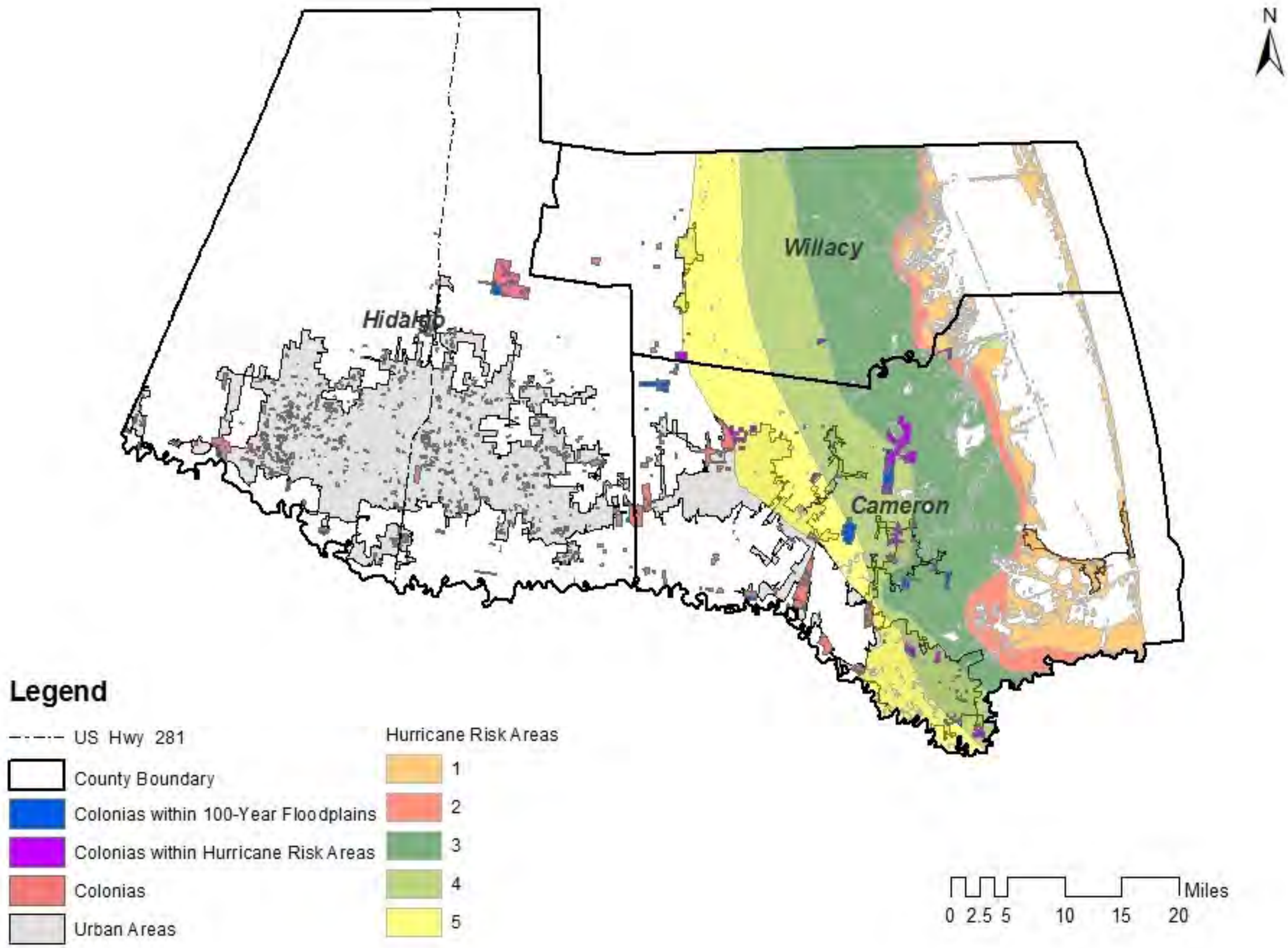


Figure 4: Colonias Overlaid with Hurricane Risk Areas and 100-year Floodplain



East as the area east of IH-69/US-281 (the roughly vertical line running North/South through the center of Hidalgo County in all four maps), which comprises ZIP codes 78516, 78537, 78538, 78539, 78558, 78562, 78570, 78577, 78589, 78596, 78543, and 78579. The remaining ZIP codes in this county comprise Hidalgo West (i.e., 78501, 78503, 78504, 78541, 78542, 78557, 78572, 78574, 78560, 78565, 78573, 78576, 78595).

Personal contact survey. A significant portion of the population of the three counties lives in colonias, which are unincorporated subdivisions of these counties that have less than standard levels of infrastructure (http://www.sos.state.tx.us/border/colonias/faqs.shtml). There are 195 colonias in Cameron County, 942 in Hidalgo, and 16 in Willacy with estimated populations of 138,458, and 3,465, respectively. As was the case with the urban populations, the large disparities in the number and population size of colonias in each county (81.7% of the total number of colonias in these three counties are in Hidalgo, 16.9% are in Cameron, and 1.4% are in Willacy) made it inadvisable to randomly select colonias in all three counties with the probability of selection proportional to the number of colonias in that county. Thus, as was the case for the general population sample, the largest number of cases was selected from Cameron County, followed by Hidalgo County and Willacy County in order to reduce the disparities in the range of plausible estimates of evacuation rates from that county. As a result of these calculations, the target distribution for the Cameron sample was 180 households, 90 from Risk Areas 1-5 and another 90 from the remainder of the county. The target distribution for the Willacy sample was 100 households, 50 from Risk Areas 1-5 and another 50 from the remainder of the county. The target distribution for the Hidalgo sample was 120 households, 40 from Hidalgo East, 40 from Hidalgo West, and another 60 from the 100-year floodplain.

There were three sampling locations in Cameron County. The first sampling location was the Rutherford-Harding Addition just west of Port Isabel on Laguna Madre, where interviewers contacted 68 households. This colonia was selected because it was inside Risk Area 1. The second sampling location was a group of contiguous colonias southeast of Brownsville comprising the Alabama/Arkansas, South Point, Unknown (Oklahoma Avenue), Valle Escondido, and Valle Hermosa colonias. Interviewers contacted 66 households in this area, which was selected because it was inside the hurricane risk area. The third sampling location was Primera Colonia, just west of Harlingen, where interviewers contacted another 66 households. This colonia was selected because it was outside the hurricane risk area.

There were two sampling locations in Willacy County. The first sampling location was the Santa Monica Colonia, southeast of Raymondville, where interviewers contacted 20 households. This colonia was selected because it was inside the hurricane risk area. The second sampling location was Sebastian Colonia, south of Raymondville, where interviewers contacted 80 households. This colonia was selected because it was outside the hurricane risk area.

There were five sampling locations in Hidalgo County. The first sampling location was a group of contiguous colonias south of Weslaco comprising the Babb RC Mobile Home, R.C. Babb Subdivision, R.C. Babb Subdivision #2, and R.C. Babb Subdivision #3 & #4 colonias, where interviewers contacted 30 households. This colonia was selected because it was inside the floodplain. The second sampling location was a group of contiguous colonias around Sullivan City comprising the Benevides Subdivision, La Aurora Subdivision, La Hermosa Subdivision, and St. Clair Acres colonias, where interviewers contacted 30 households. This colonia was also selected because it was inside the floodplain. The third sampling location was a group of contiguous colonias north of Edinburg comprising the Bar #5, Hern Subdivision, and Santa Cruz Estates colonias, where interviewers contacted 30 households. This colonia was selected because it was outside the floodplain. The fourth sampling location was a group of contiguous colonias north of Edinburg comprising Doolittle Acres, Hillcrest Terrace, Ingle-Doolittle, Triple C Subdivision, and Sandy Ridge colonias, where interviewers contacted 30 households. This colonia was selected because it was outside the floodplain. The fifth sampling location was a group of contiguous colonias northeast of Weslaco comprising La Paloma #1, Sunrise Hill, and Wes-mer Subdivision colonias, where interviewers contacted 30 households. This colonia was selected because it was outside the floodplain. Figure 4 shows the distribution of the selected colonias that are overlaid with hurricane risk areas and/or 100-year floodplains.

Questionnaire

Respondents were asked to fill out a questionnaire comprising 27 items examining their previous hurricane experience, information sources, evacuation intentions, perceived personal impact, evacuation logistics requirements, evacuation logistics plan, hurricane risk perceptions, emergency preparedness, geographic characteristics, and demographic characteristics (see Appendix A). This questionnaire was based upon an earlier one that HRRC staff used in their 2000 Hurricane Evacuation Behavior study (Lindell et al., 2001). Specifically, the questionnaire addressed Objective 1 (To determine the number of potential evacuees and evacuating vehicles within the three county study area under various tropical storm/hurricane scenarios—e.g. Tropical Storm, and Category 1-5 hurricanes) using Questions 3-8, 14, 15 and 23. In addition, the self-reported hurricane risk area (Q14) and inland flood zone (Q15) items were compared to geocoded assessments of respondents' home address to determine whether respondents' self-reports of their risk areas were accurate. The questionnaire addressed Objective 2 (Determine the evacuee destinations and where the evacuees plan to seek accommodations) using Questions 9-11. The questionnaire addressed Objective 3 (Determine the general level of awareness, hurricane experience, and evacuation experience of the vulnerable population and how this experience may affect the decision to evacuate) using Questions 1 and 12. The questionnaire addressed Objective 4 (Determine the significant factors influencing the population's decisions to evacuate or stay (e.g., local officials, personal resources, border security checkpoints, social influences, media, job, etc.) using Questions 2, 4, 13-15, and 24-26. Finally, the questionnaire addressed Objective 5 (Determine the timeframe and how the threatened population will evacuate in response to official evacuation orders and various defined forecast storm conditions such as category of hurricane, and potential flooding) using Question 3.

There are two significant language impediments to questionnaire administration in the VSA area. The first is that, as indicated in Table 1, a sizable proportion of the population of these three counties speaks a language other than English in the home. The percentage is almost a majority in Willacy County and is the overwhelming majority in the other two counties. To overcome this impediment, a bilingual staff member of the Texas A&M University Colonias Program, who had lived in the area for most of her life, translated the questionnaire into Spanish. The Spanish version of the questionnaire was independently back-translated to English by another bilingual member of the Colonias Program staff who was equally proficient in English and Spanish. The two staff members reconciled differences between the original and back-translated English versions by discussion about the appropriate translation. Subsequently, both English and Spanish versions of the cover letter and questionnaire were included in each questionnaire packet in the mail survey.

Table 1. Language Impediments to Questionnaire Administration (%)

County	Language other than English spoken in the home	Illiteracy
Cameron	73	43
Hidalgo	85	50
Willacy	45	40

Sources: *www-tcall.tamu.edu/docs/09illitmap.html* and *quickfacts.census.gov/*

The second language impediment to questionnaire administration is the high level of illiteracy in this area. As Table 1 indicates, the illiteracy rate is about 40-50% of the population in each of the three counties. To overcome this impediment, the Texas A&M University Colonias Program hired three bilingual interviewers who made personal contact with a member of each of the households in the colonias sample and, as noted above, either dropped off a questionnaire packet after contacting a member of the household and judging that the respondent was sufficiently literate to complete the questionnaire or read the cover letter and questionnaire to the respondent and recorded the responses to each of the questions.

Data Collection

Mail survey. Each selected household was sent a packet containing a cover letter, a questionnaire, and a stamped self-addressed reply envelope. A reminder post card was sent to those who did not return a completed questionnaire within two weeks. Replacement packets were sent at two-week intervals thereafter. This process was terminated when the respondents had either returned a completed questionnaire or had received one reminder post card and three questionnaire packets. Of the 1,198 selected households, 106 households were either undeliverable or refused to respond the survey and 254 households returned usable questionnaires for a response rate of 23.3%. This response rate is somewhat lower than previous mail surveys conducted by HRRC—50.7% from Hurricane Lili evacuation survey by Lindell, et al. (2005), 33.5% from Hurricane Katrina two parish mail survey by Lindell and Prater (2008), 35.6% from Hurricane Rita seven county mail survey by Lindell and Prater (2008), and 39.4% from Hurricane Ike evacuation and reentry survey by Huang et al. (2010). However, it was comparable to the 25.7% response rate in the Hurricane Bret evacuation survey by Prater et al. (2000) and the 24.6% response rate in the Texas coastal evacuation expectations survey by Lindell et al. (2001), both of which included samples from VSA.

The mail survey respondents were predominantly female (56%), Hispanic (76%), White (97%), married (67%), and homeowners (96%). The respondents tended to be middle-aged (arithmetic mean, M = 55.7 years) and, on average, had fewer years of education (13.5 years) and lower annual household income ($33,432 USD) than the US average. The responding households averaged 3.3 persons in size and had an average of 0.9 children under the age of 18.

Personal contact survey. Interviewers were given maps of their interview locations and instructed to go to the starting point on the route for each colonia and follow the instructions for selecting each house at which to administer the questionnaire. These instructions included a randomly selected starting house and a sampling interval between houses. Before contacting each house, interviewers checked a *Duplicate Address* list to see if the address had already received a mail questionnaire. If so, they were instructed to go to the next house they would have contacted and to continue the sampling interval they had been using to contact additional households until they ran out of questionnaires.

At each house, the interviewers introduced themselves in Spanish or English, whichever they thought would suit the respondent, and explained that they were conducting a survey about people's expectations of how they and their families would respond to a hurricane approaching their community. The interviewer told the respondent that this survey was a cooperative effort of the Texas A&M University Hazard Reduction & Recovery Center, the Texas A&M University Colonias Program, and their county emergency management agency. If an adult of the appropriate sex was available (interviewers were told to alternate males and females at each residence), the interviewers told the adult(s) of the household that they could interview them for about 30 minutes or leave a questionnaire for the resident to fill out at their convenience. Residents who chose to fill out a questionnaire were told the questionnaire packets contained both Spanish and English copies of the cover letter and questionnaire, that they could fill out whichever version they preferred and that, when they were finished, they should put the completed questionnaire into the return envelope and send it back to us in the mail. If no one answered the door, the interviewers checked back on different days and different times during the day but discontinued callbacks if they were not successful in contacting an adult at that address by the fourth attempt.

Of the 450 colonias households that the interviewers contacted, they interviewed 203 face-to-face, left questionnaires for 205 to complete independently, and were refused by 42. This yielded 227 completions for an overall response rate of 50.4% but there was a substantial disparity between the response rates for those households where questionnaires were dropped off (22.0%) and those that were personally interviewed (89.7%).

The colonias respondents were predominantly female (56%), Hispanic (96%), White (97%), married (73%), and homeowners (82%). The respondents tended to be middle-aged (arithmetic mean, M = 51.1 years) and, on average, had fewer years of education (11.5 years) and lower annual household income ($22,951) than the US average. The responding households averaged 3.6 persons in size and had an average of 1.1 children under the age of 18.

Evaluation of the Survey Response

The response rate in the urban (mail) sample was about half of our original goal—a 50% response rate of the entire population—but it did represent about 50% of the *literate* population. The overall response rate in the colonias sample did meet our original goal—a 50% response rate of the entire population. To put these response rates into perspective, it is important to note that the Pew Research Center for the People and the Press (2012) recently reported that survey response rates, defined as the percent of households sampled that yielded an interview, have been declining substantially for more than a decade. Telephone interviews, which tend to have response rates intermediate between those of personal interviews (the highest response rates) and mail questionnaires (the lowest response rates), fell from an average of 36% in 1997 to an average of 9% in 2012. Nonetheless, this report concluded that properly conducted surveys can still provide accurate data. Thus, although the response rates for the urban mail survey and the colonias dropoff survey were below our targets, they exceed the average performance of surveys nationwide and are likely to provide a satisfactory basis for making projections about people's expected responses to approaching hurricanes.

RESULTS

Hurricane Experience

The questionnaire began by asking respondents to report what type of experience they previously had with hurricanes. As the first row of the second column in Table 2 indicates, about one third of the urban respondents (37.2%) lacked previous hurricane experience. The cell in the second row of that column displays the percentage of urban non-evacuees who had previously experienced a hurricane evacuation warning and their communities were hit by the hurricane (32.8%) whereas the cell in the third row of that column displays the percentage of urban non-evacuees who had previously experienced a hurricane evacuation warning but their communities were missed by the hurricane (14.8%). The cell in the fourth row of that column displays the percentage of urban evacuees who had previously experienced a hurricane evacuation warning and whose communities were hit by the hurricane (9.6%) whereas the cell in the fifth row of that column displays the percentage of urban evacuees who had previously experienced a hurricane evacuation warning and whose communities were missed by the hurricane (5.6%).

Table 2. Previous Response to Hurricane Evacuation Warnings (%)

	Urban Sample			Colonias Sample		
	Frqcy	Percent[a]	Percent[b]	Frqcy	Percent[a]	Percent[b]
Inexperienced	93	37.2	-	90	40.0	-
Stayed but hit	82	32.8	52.2	67	29.8	49.6
Stayed and missed	37	14.8	23.6	22	9.8	16.3
Evacuated and hit	24	9.6	15.3	30	13.3	22.2
Evacuated but missed	14	5.6	8.9	16	7.1	11.9
Total	250	100.0	100.0	225	100.0	100.0

[a] Percentage of all respondents
[b] Percentage of respondents with hurricane experience

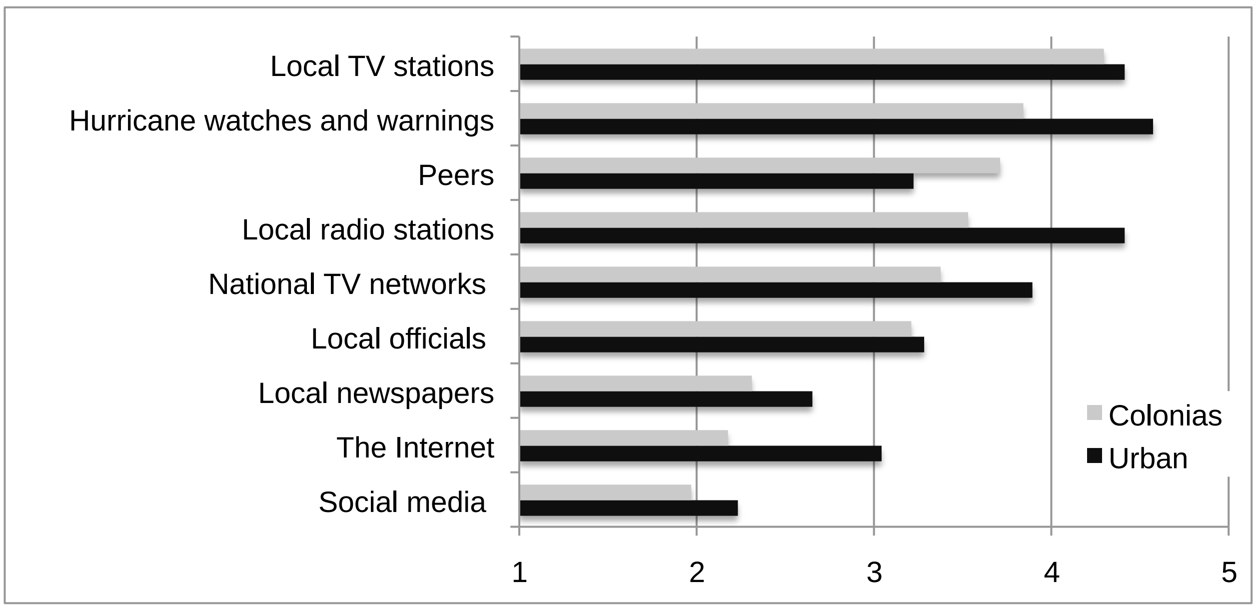
We recomputed the percentages in this table to assess the percentages, *among those who did have previous hurricane experience*, of the four different types of outcomes. Thus, the cell in first row of the third column is blank because those who had never been hit by a hurricane were eliminated from this calculation. However, the second and third rows of this column show that, of those urban residents who had experienced a hurricane evacuation warning, approximately half (52.2%) reported they stayed and the hurricane hit their community whereas a quarter (23.6%) of respondents reported they stayed and the hurricane missed their community. Finally, the fourth and fifth rows of this column reveal that only a small portion (15.3% + 8.9% = 24.2%) of the urban respondents had hurricane evacuation experience.

The right-hand portion of the table indicates that the colonias residents reported very similar levels of hurricane evacuation warning experience as well as very similar responses to the warnings. Specifically, many (40%) never had experienced a hurricane and, of those who had, only a minority of them evacuated (22.2% + 11.9% = 34.1%).

Information Sources

Respondents were asked to judge the extent (on a scale from 1-5, where 1 = *not at all* and 5 = *very great extent*) of the information sources they would rely on when they decide whether to evacuate from a future hurricane. Figure 5 shows that both urban and colonias respondents would rely substantially on National Hurricane Center hurricane watches and warnings (*Colonias* = 4.29; *Urban* = 4.57) and local TV stations (*Colonias* = 3.84; *Urban* = 4.41) as their primary information sources, followed by national TV networks (*Colonias* = 3.37; *Urban* = 3.89) and local radio stations (*Colonias* = 3.53; *Urban* = 3.85). Respondents expect to depend to only a moderate extent on local officials (*Colonias* = 3.21; *Urban* = 3.28), peers such as friends, relatives, neighbors, or coworkers (*Colonias* = 3.71; *Urban* = 3.22), and the Internet (*Colonias* = 2.17; *Urban* = 3.04). Finally, they expect to rely on information from local newspapers (*Colonias* = 2.31; *Urban* = 2.65) and social media (*Colonias* = 1.97; *Urban* = 2.23) to only a minimal extent.

Figure 5: Expected Reliance on Information Sources



The most notable differences between the two groups are that, compared to the colonias residents, the urban residents expect to rely more on hurricane watches and warnings, local radio, national TV, and the Internet but slightly less on peers.

Evacuation Expectations

Respondents were also asked to indicate their intentions to evacuate in response to each of the six categories of storm (Tropical Storm and hurricanes in Category 1-5) if they were advised by local authorities to do so. As Table 3 indicates, the expected evacuation rate increases from

Tropical Storm (15.9%) to Category 5 Hurricane (93.6%) for the urban respondents and from Tropical Storm (32.3%) to Category 5 Hurricane (94.1%) for the colonias respondents. Overall, Table 3 indicates the colonias residents are significantly more likely than urban residents to evacuate from minor storms (Tropical Storm through Category 2).

Table 4a presents data on the percentage of urban respondents who expect to evacuate from each hurricane risk area (locations Barrier Island through Risk Area 5 in the left column) for each storm category (Tropical Storm through Category 5 in the top row). Respondents' expected evacuation decisions are strongly and statistically significantly related ($\phi = .62$, $p < .001$) to their official hurricane risk area. The ϕ coefficient is an index that ranges from 0 (no association) to 1 (perfect association).

Table 3. Respondents' Evacuation Expectations by Storm Intensity (%)

Expected intensity	Evacuation decision	
	Urban[a]	Colonias[b]
Tropical Storm	15.9	32.3
Category 1	30.4	53.2
Category 2	56.2	69.8
Category 3	82.2	85.5
Category 4	92.1	93.2
Category 5	93.6	94.1

[a] $218 \leq N \leq 230$; [b] $220 \leq N \leq 224$

Table 4a reveals two important evacuation phenomena. The first important phenomenon is *incomplete compliance*. Although emergency managers would hope that everyone in Risk Area 1 would evacuate from a Category 1 hurricane, everyone in Risk Areas 1 and 2 would evacuate from a Category 2 hurricane, and so on through everyone in Risk Areas 1-5 evacuating from a Category 5 hurricane, this is not the case. For example, only 75% of those on the Barrier Island and only 50% of those in Risk Area 1 would evacuate from a Category 1 hurricane. Similarly, a Category 4 hurricane would elicit only 80% compliance in Risk Area 3 and 89% compliance in Risk Area 4—although there would be 100% compliance from the Barrier Island and Risk Area 1 groups. The $\chi 2$ tests of statistical significance indicate that there were no statistically significant differences among the locations in their residents' expectations of evacuating in response to each category of storm.

The other important phenomenon is *shadow evacuation*, which is evacuation by those who do not need to do so. The percentage of shadow evacuation for a Category 1 hurricane ranges from 40% in Risk Area 3 to 27% from the Inland Area. The problem of shadow evacuation could be especially acute as a Category 3 hurricane approaches Valley Study Area (VSA) because 72% of those in Risk Area 4, 81% of those in Risk Area 5, and 80% of those from the Inland Area expect to evacuate for this storm category.

Overall, the rate of increase in the proportion of shadow evacuees is nearly constant for a Tropical Storm through a Category 3 hurricane, with the proportion of respondents expecting to evacuate increasing by an average of 22% with each increase in storm intensity. The proportion of shadow evacuees increases only slightly in a Category 4 hurricane and there is a negligible increase beyond that for a Category 5 hurricane. It should also be noted that the average shadow evacuation rate from the Inland Area also steadily increases with hurricane intensity.

Table 4a. Cameron and Willacy County Urban Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Risk Area	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Barrier Island	50.0	75.0	100.0	100.0	100.0	100.0
1	19.0	50.0	76.2	100.0	100.0	100.0
2	-	-	-	-	-	-
3	20.0	40.0	66.7	80.0	80.0	80.0
4	11.8	23.5	50.0	72.2	88.9	100.0
5	22.8	29.5	46.8	80.8	93.5	94.4
Inland	9.7	27.1	59.6	80.2	90.5	91.2
	χ_5^2 = 9.1 p > .05	χ_5^2 = 8.7 p > .05	χ_5^2 = 10.3 p > .05	χ_5^2 = 7.0 p > .05	χ_5^2 = 4.0 p > .05	χ_5^2 = 5.5 p > .05

Note: The row for Risk Area 2 displays no data because there were no respondents from Risk Area 2.

Table 4b shows that the relationship between risk area and evacuation expectations for colonias residents is more extreme than for the urban residents. For example, comparison of Tables 4a and 4b shows that the percentage of Inland colonias residents who expect to evacuate from a Tropical Storm is 36.6% whereas the percentage of Inland urban residents who expect to evacuate from a storm of this intensity is only 9.7%. Moreover, the percentage of Inland colonias residents who expect to evacuate from each of the more intense storm categories is higher than the corresponding percentage of Inland urban residents who expect to evacuate from the same storm category. However, the sizes of the differences between the colonias and urban residents decrease as the storm intensity increases.

In addition, the same pattern can generally be seen in the data for Risk Areas 1, 4 and 5. It is not possible to compare responses from colonias and urban residents living on the barrier island because there are no colonias on the barrier island. Moreover, it is not possible to compare responses from colonias and urban residents living in Risk Areas 2 or 3 because no questionnaires were returned from Risk Area 2 and only one questionnaire was returned from Risk Area 3. In Table 4b, the $\chi 2$ tests of statistical significance indicate that there were statistically significant differences among the locations in their residents' expectations of evacuating in response to Category 2 and 3 storms, but not the other categories.

Table 4b. Cameron and Willacy County Colonias Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Risk Area	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Barrier Island	-	-	-	-	-	-
1	0.0	70.6	94.1	100.0	100.0	100.0
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	30.0	60.0	73.3	80.0	86.7	86.7
5	34.0	38.8	54.0	72.0	92.0	92.0
Inland	36.6	54.8	71.8	90.2	94.3	95.9
	$\chi^2_5 = 9.3$ $p > .05$	$\chi^2_5 = 6.9$ $p > .05$	$\chi^2_5 = 11.5$ $p < .05$	$\chi^2_5 = 13.2$ $p < .05$	$\chi^2_5 = 3.6$ $p > .05$	$\chi^2_5 = 5.2$ $p > .05$

Note: None of the colonias was on the barrier island, no questionnaires were returned from Risk Area 2, and only one questionnaire was returned from Risk Area 3.

We combined the data for the urban and colonias samples to produce a table that has a larger sample size and, thus, more stable estimates of the expected evacuation rates from each risk area at each storm category. The resulting data are presented in Table 4c.

Table 4c. Cameron and Willacy County Combined Urban and Colonias Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Risk Area	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Barrier Island	50.0	75.0	100.0	100.0	100.0	100.0
1	16.8	52.4	78.3	100.0	100.0	100.0
2	-	-	-	-	-	-
3	20.0	40.0	66.7	80.0	80.0	80.0
4	13.9	27.8	52.7	73.1	88.6	98.4
5	24.1	30.6	47.6	79.8	93.3	94.1
Inland	12.8	30.3	61.0	81.4	90.9	91.7

Hidalgo County is outside the hurricane risk areas but previous hurricane evacuation research has shown that there can be significant levels of evacuation shadow from inland areas. The level of evacuation shadow is likely to vary according to the proximity of each household's location to the hurricane risk areas and also its location in floodplains. Table 4d shows the rates of evacuation expectations for urban residents in Hidalgo East, Hidalgo West, and Hidalgo 500 year floodplain by storm category. As one would expect, the expected evacuation rates are higher for Hidalgo East than for Hidalgo West, and the latter is approximately the same as the Hidalgo 500 year floodplain. However, the $\chi 2$ tests of statistical significance indicate that there was a statistically significant difference among the locations in their residents' expectations of evacuating only in response to a Tropical Storm, but not for any of the five hurricane categories.

Table 4d. Hidalgo County Urban Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Location	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
East	40.0	50.0	80.0	100.0	100.0	100.0
West	8.3	28.0	56.0	79.2	92.3	95.7
500 yr floodplain	8.0	25.9	53.6	81.5	92.3	92.3
	χ^2_2 = 7.2 p = .028	χ^2_2 = 2.1 p > .05	χ^2_2 = 2.3 p > .05	χ^2_2 = 2.2 p > .05	χ^2_2 = 0.7 p > .05	χ^2_2 = 0.9 p > .05

As indicated by Table 4e, the Hidalgo County colonias residents had a different pattern from the Hidalgo County urban residents because the expected evacuation rates for the colonias residents were roughly the same regardless of location—East, West, and 500 year floodplain. This observation is confirmed by the $\chi 2$ tests of statistical significance, which indicate that there were no statistically significant differences among the locations in their residents' expectations of evacuating in response to each category of storm.

Table 4e. Hidalgo County Colonias Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Location	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
East	43.5	60.9	73.9	90.9	90.9	90.9
West	43.9	56.1	71.2	89.6	94.0	95.5
500 yr floodplain	38.5	64.3	71.4	85.7	92.9	100.0
	χ^2_2 = 0.1 p > .05	χ^2_2 = 0.4 p > .05	χ^2_2 = 0.1 p > .05	χ^2_2 = 0.3 p > .05	χ^2_2 = 0.3 p > .05	χ^2_2 = 1.6 p > .05

As with the Cameron and Willacy County samples, we combined the urban and colonias samples by weighting the results from Tables 4d and 4e according to their proportions in the county population. The combined estimates of expected evacuation rates are presented in Table 4f.

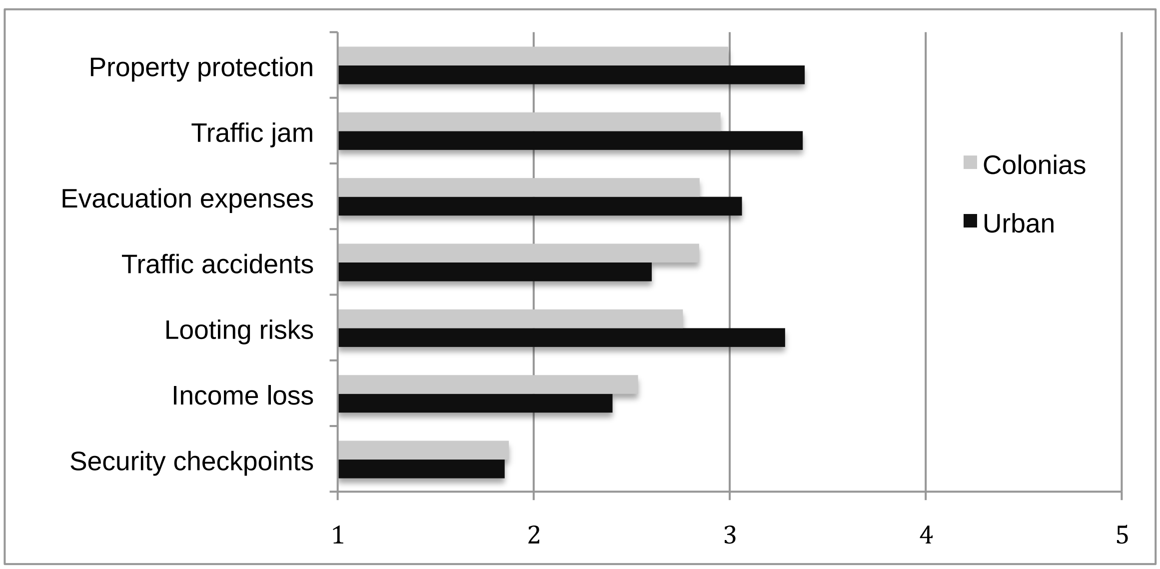
Table 4f. Hidalgo County Combined Urban and Colonias Residents' Evacuation Expectations by Location in Official Hurricane Risk Area (%)

Location	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
East	40.6	52.0	78.9	98.4	98.4	98.4
West	14.7	33.0	58.7	81.1	92.6	95.7
500 yr floodplain	13.5	32.8	56.8	82.3	92.4	93.7

Evacuation Inhibitors

Respondents were asked to judge (on a scale from 1-5, where 1 = *not at all* and 5 = *very great extent*) the extent to which traffic accidents, traffic jams, property protection, income loss, evacuation expenses, looting risks, and security checkpoints would affect their evacuation decisions. Figure 6 reveals that the colonias and urban residents were relatively similar in their responses. They were moderately concerned about protecting their property from the storm (*Colonias* = 2.99; *Urban* = 3.38), being caught in traffic jams (*Colonias* = 2.95; *Urban* = 3.37), and evacuation expenses (*Colonias* = 2.84; *Urban* = 3.06). They were somewhat less concerned about traffic accidents (*Colonias* = 2.84; *Urban* = 2.60), looting risks (*Colonias* = 2.76; *Urban* = 3.28), and income loss (*Colonias* = 2.53; *Urban* = 2.40). All Valley households expressed only minimal concern about security checkpoints (*Colonias* = 1.87; *Urban* = 1.85). Overall, the urban residents tended to be somewhat more concerned than colonias residents about protecting their property from the storm, getting caught in traffic jams, and looting risks.

Figure 6: Evacuation Concerns



Evacuation Impediments

When asked about evacuation impediments, 16.5% of the urban respondents and 16.8% of the colonias residents reported that they have household members needing special medical assistance to evacuate. In addition, 55.3% of the urban respondents and 39.9% of the colonias residents reported having pets needing to be evacuated along with household members.

Evacuation Modes

Urban residents reported an average of 2.15 registered vehicles per household but expected to take 1.52 cars or trucks, 0.03 recreational vehicles, and 0.05 trailers—1.60 vehicle equivalents or 74.4% of the registered vehicles. Colonias residents reported an average of 2.09 registered vehicles per household but would only take 1.52 cars or trucks, 0.03 recreational vehicles, and 0.08 trailers. This is a total of 1.63 vehicle equivalents or 78.0% of the registered vehicles.

For those who do not have their own personal vehicle, 14.6% of the urban residents reported that they would take public transportation, 78.1% would seek rides with peers, and 7.3% would use other modes of transportations such as a business vehicle. Similarly, 8.7% of the colonias residents reported that they would take public transportation, 88.4% would seek rides with peers, and 2.9% would use other modes of transportations such as a business vehicle.

Evacuation Destinations

Figure 7 indicates that 58.3% of the urban respondents and 47.8% of the colonias residents expected to go to destinations in South Texas but there were notable differences in the percentages that would evacuate to inland area of VSA (*Colonias* = 29.4%; *Urban* = 8.8%). Of the remainder, 18.5% of the urban residents and 15.0% of the colonias residents expected to go elsewhere in Texas, 4.2% of the urban residents and 3.5% of the colonias residents would go to other places in the U.S. outside of Texas, and only 3.2% of the urban respondents and 1.5% of the colonias residents would evacuate to cities in Mexico.

Figure 7: Expected Evacuation Destination Regions

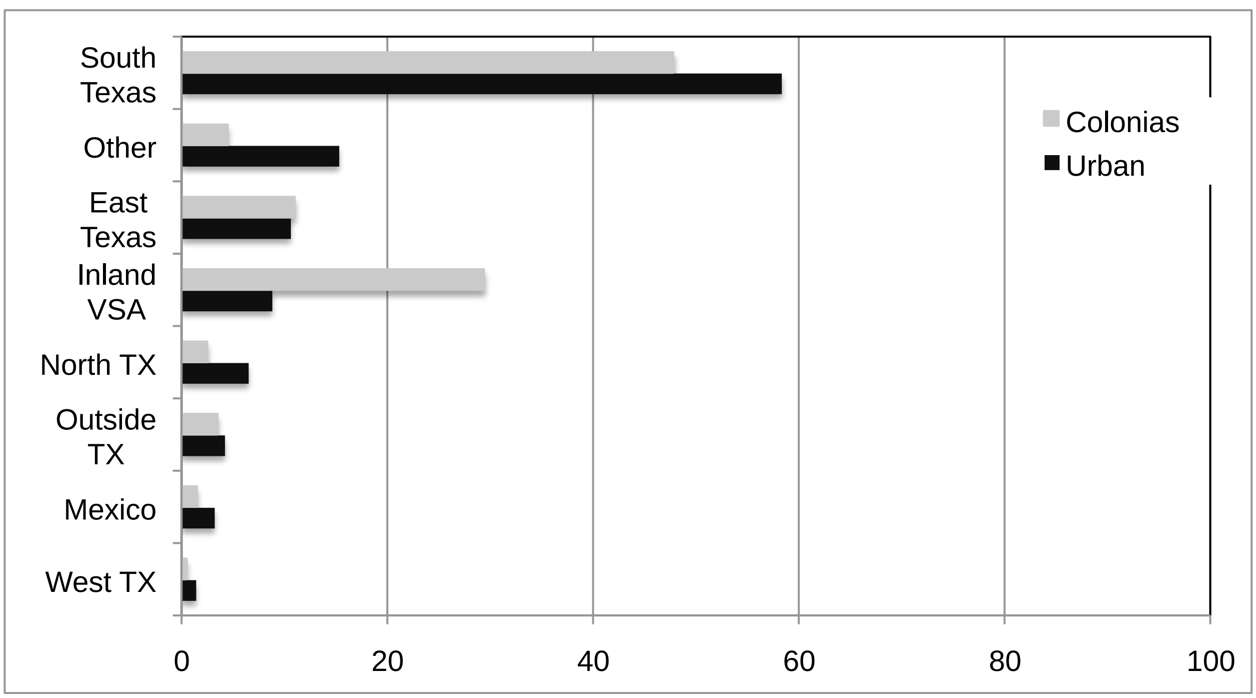


Table 5a indicates an average of 47.8% of the urban VSA residents named San Antonio as their evacuation destination, followed by Houston and Austin with 11.5% and Laredo with 10.4%. Smaller percentages expected to evacuate to Dallas and McAllen (6.0%), or to cities in Mexico (4.4%). The $\chi 2$ tests of statistical significance indicate that there were no statistically significant differences among the counties in their residents' expectations of evacuation destinations.

Table 5a. Urban Residents' Expected Evacuation Destination Cities, by County (%)

	Cameron	Willacy	Hidalgo	Total	$\chi 2$	*p* Value
1. San Antonio	46.7	43.9	53.1	47.8	0.8	> .05
2. Houston	9.8	19.5	8.2	11.5	3.4	> .05
3. Austin	8.7	17.1	12.2	11.5	2.0	> .05
4. Laredo	12.0	7.3	10.2	10.4	0.7	> .05
5. Dallas	8.7	4.9	2.0	6.0	2.6	> .05
6. McAllen	8.7	7.3	0.0	6.0	4.4	> .05
7. City in Mexico	4.3	0.0	8.2	4.4	3.5	> .05
8. Brownsville	2.2	0.0	0.0	1.1	2.0	> .05
9. Edinburg	0.0	0.0	4.1	1.1	5.5	> .05
10. Harlingen	1.1	2.4	0.0	1.1	1.2	> .05
11. Other Cities (less than 1%)	14.1	12.2	14.3	13.7	0.1	> .05

Table 5b reveals that an average of 30.2% of the colonias VSA residents also chose San Antonio as their evacuation destination, followed by Houston (10.6%) but McAllen (12.6%) was more popular than Austin (6.5%). Laredo (3.5%) was less popular with colonias residents than with urban residents, but Harlingen (6.5%) was only slightly more popular and the remaining cities received negligible percentages of the nominations. The $\chi 2$ tests indicate that there were statistically significant differences among the counties in their residents' choices of three evacuation destinations—Houston (much more popular in Hidalgo County), McAllen (much more popular in Cameron County), and Harlingen (somewhat less popular in Hidalgo county).

Table 5b. Colonias Residents' Expected Evacuation Destination Cities, by County (%)

	Cameron	Willacy	Hidalgo	Total	$\chi 2$	*p* Value
1. San Antonio	36.7	35.8	23.7	30.2	3.7	> .05
2. Houston	2.0	3.8	18.6	10.6	12.9	= .002
3. Austin	4.1	11.3	5.2	6.5	2.8	> .05
4. Laredo	4.1	0.0	5.2	3.5	2.7	> .05
5. Dallas	0.0	1.9	4.1	2.5	2.4	> .05
6. McAllen	26.5	5.7	9.3	12.6	12.0	= .003
7. City in Mexico	0.0	0.0	3.1	1.5	3.2	> .05
8. Brownsville	0.0	0.0	0.0	0.0	-	-
9. Edinburg	2.0	0.0	2.1	1.5	1.1	> .05
10. Harlingen	6.1	7.5	0.0	3.5	7.1	= .029
11. Other Cities (less than 1%)	16.3	26.4	27.8	24.6	2.4	> .05

Table 5c, which displays the weighted average of the responses from the urban (Table 5a) and colonias (Table 5b) residents, shows that almost half of the residents in all three counties plan to evacuate to San Antonio. Nearly twice as many Willacy County residents expect to go to Houston and Austin as residents of the other two counties. Slightly more Cameron County residents expect to go to Laredo, Dallas, and McAllen as residents of other counties and more Hidalgo County residents expect to go to cities in Mexico.

Table 5c. VSA Residents' Expected Evacuation Destinations, by County (%)

	Cameron	Willacy	Hidalgo	VSA Overall
1. San Antonio	45.5	43.0	47.8	47.0
2. Houston	8.9	17.7	10.1	9.8
3. Austin	8.2	16.4	10.9	10.1
4. Laredo	11.1	6.4	9.3	9.9
5. Dallas	7.7	4.5	2.4	4.2
6. McAllen	10.8	7.1	1.7	4.8
7. City in Mexico	3.8	0.0	7.3	6.0
8. Brownsville	1.9	0.0	0.0	0.7
9. Edinburg	0.2	0.0	3.7	2.5
10. Harlingen	1.7	3.0	0.0	0.6
11. Other Cities (less than 1%)	14.4	13.9	16.7	15.9

Evacuation Routes

Table 6a indicates that the most common evacuation routes for urban residents within VSA would be US-77 (48.8%), US-281 (40.8%), and US-83 (25.8%). In addition, many urban residents plan to take I-37 (9.9%) as an evacuation route once they get to Corpus Christi or I-35 (9.4%) once they reach Laredo. SH-100 (5.2%) and SH-186 (4.7%) were mentioned by few respondents, but this is because they are feeder routes to major highways. These results are consistent with the respondents' expected evacuation destinations, which are primarily cities in South Texas—San Antonio and Laredo—or just beyond (Austin and Houston). There was only a small percentage of respondents who listed other evacuation routes (2.8%) or no evacuation route (7.5%). Thus, overall, there is relatively little uncertainty about the traffic demand on primary evacuation routes when authorities initiate an evacuation. In particular, there are likely to be few households that delay initiating evacuation because they have not selected an evacuation route or destination.

There were statistically significant differences among counties in urban residents' choices of most evacuation routes. Cameron County residents were less likely to choose US-281, but more likely to name I-37 and SH-100. Willacy County urban residents were less likely to choose US-83 and more likely to choose SH-186, whereas Hidalgo County residents were less likely to choose US-77 and more likely to be uncertain about which route to take.

Table 6a. Urban Residents' Expected Evacuation Routes (%)

	Cameron	Willacy	Hidalgo	Total	$\chi 2$	*p* Value
1. US-77	66.3	59.3	14.1	48.8	44.9	< .001
2. US-281	23.2	55.6	54.7	40.8	22.2	< .001
3. US-83	31.6	11.1	29.7	25.8	8.2	= .016
4. I-37	16.8	1.9	6.3	9.9	10.0	= .007
5. I-35	8.4	14.8	6.3	9.4	2.7	> .05
6. SH-100	11.6	0.0	0.0	5.2	14.4	< .001
7. SH-186	0.0	18.5	0.0	4.7	30.9	< .001
8. US-59	0.0	5.6	3.1	2.3	4.9	> .05
9. I-10	0.0	1.9	1.6	0.9	1.7	> .05
10. Other Routes	3.2	1.9	3.1	2.8	0.3	> .05
11. N/A	5.3	1.9	15.6	7.5	9.2	= .01

Note: Some respondents listed more than one evacuation route; the percentages were calculated by dividing the frequency that each route was mentioned by the total number of routes mentioned.

Table 6b indicates that the most common evacuation routes for colonias residents within VSA would also be US-77 (44.9%), US-281 and US-83 (33.5%). In addition, many colonias residents plan to take I-37 (8.6%) as an evacuation route once they get to Corpus Christi and a few plan to take I-35 (3.8%) once they reach Laredo. SH-100 (5.2%) and SH-186 (4.7%) were mentioned by few respondents but, as with urban residents, this is because they are feeder routes to major highways. As was the case with the urban residents, these results are consistent with the respondents' expected evacuation destinations, which are primarily San Antonio, Laredo, Austin and Houston.

Table 6b. Colonias Residents' Expected Evacuation Routes (%)

	Cameron	Willacy	Hidalgo	Total	$\chi 2$	*P* Value
1. US-77	76.9	94.4	9.3	44.9	107	< .001
2. US-281	1.9	2.8	61.9	33.5	73.5	< .001
3. US-83	57.7	5.6	30.9	33.5	26.6	< .001
4. I-37	5.8	30.6	2.1	8.6	27.7	< .001
5. I-35	5.8	5.6	2.1	3.8	1.7	> .05
6. SH-100	25.0	0.0	0.0	7.0	35.8	< .001
7. SH-186	0.0	2.8	0.0	0.5	4.2	> .05
8. US-59	1.9	0.0	0.0	0.5	2.6	> .05
9. I-10	0.0	5.6	1.0	1.6	4.6	> .05
10. Other Routes	1.9	2.8	0.0	1.1	2.4	> .05
11. N/A	0.0	8.3	5.1	4.3	3.9	> .05

Note: Some respondents listed more than one evacuation route; the percentages were calculated by dividing the frequency that each route was mentioned by the total number of routes mentioned.

There was only a small percentage of colonias residents who listed other evacuation routes (1.1%) or no evacuation route (4.3%). Thus, colonias residents will also contribute little uncertainty about the traffic demand on primary evacuation routes. In particular, there are likely to be few colonias households that delay initiating evacuation because they have not selected an evacuation route or destination.

There were statistically significant differences among counties only in colonias residents' choices of the most popular evacuation routes. Cameron County residents were more likely to choose US-83 and SH-100. Willacy County colonias residents were more likely to choose US-77 and I-37, whereas Hidalgo County residents were less likely to choose US-77, more likely to choose US-281, and more likely to be uncertain about which route to take.

Table 6c, which displays the weighted average of the responses from the urban (Table 6a) and colonias (Table 6b) residents, reveals that the most common routes evacuees plan to take within VSA are US-281 (44.0%), US-77 (32.5%), and US-83 (31.2%) but there are noticeable differences among counties in people's evacuation route choices. Cameron County residents plan to rely heavily on US-77, somewhat less on US-83, and still less on US-281 and SH-100 and, after leaving VSA, use I-37. Willacy County residents plan to rely heavily on US-77, somewhat less on US-281, and significantly less on SH-186, US-83, and I-35. Hidalgo County residents plan to take US-281, US-77, and US-83—although quite a few have not yet planned an evacuation route.

Evacuation Accommodations

Respondents were asked where they expected to stay while away from home during a hurricane evacuation. Figure 8 shows that homes of friends and relatives (*Colonias* = 54.0%; *Urban* = 45.3%) were generally the most popular destinations, but there were notable differences in the popularity of the other two types of evacuation accommodations. Urban residents were more likely (33.3%) than colonias residents (19.7%) to expect to go to a hotel or a motel whereas colonias residents were much more likely (20.2%) than urban residents (6.4%) to expect to go to public shelters. Moreover, urban residents were somewhat more likely (12.4%) than colonias residents (5.2%) to be uncertain about where they would stay while evacuating. Only a few people (*Colonias* = 0.9%; *Urban* = 2.6%) listed other types of accommodations such as second homes.

Expected Hurricane Impacts

Respondents were asked to judge (on a scale from 1-5, where 1 = *not at all likely* and 5 = *almost certain*), their expectations of the likelihood that a hurricane would occur in the next five years that would cause damage to their area, injury to people in their community, damage to their home from storm wind, damage to their home from storm surge, damage to their home from flooding, injury to themselves or their families, disruption to their jobs, or disruption to community infrastructure such as electric, telephone, and other services.

Table 6c. VSA Residents' Expected Evacuation Routes, by County (%)

	Cameron	Willacy	Hidalgo	VSA Overall
1. US-77	67.5	63.4	13.2	32.5
2. US-281	20.7	49.4	56.0	44.0
3. US-83	34.7	10.5	29.9	31.2
4. I-37	15.5	5.3	5.5	8.9
5. I-35	8.1	13.7	5.5	6.6
6. SH-100	13.2	0.0	0.0	4.4
7. SH-186	0.0	16.7	0.0	0.3
8. US-59	0.2	4.9	2.5	1.8
9. I-10	0.0	2.3	1.5	1.0
10. Other Routes	3.0	2.0	2.5	2.7
11. N/A	4.7	2.6	13.7	10.5

Note: The total percentage is greater than 100% because some respondents reported multiple highways.

Figure 9 shows that respondents judged infrastructure disruption (*Colonias* = 4.18; *Urban* = 3.88) to be the most likely result of a hurricane strike, followed by property damage in their community (*Colonias* = 3.31; *Urban* = 3.17) and damage to their homes from wind (*Colonias* = 3.35; *Urban* = 3.22). Respondents expected that property damage to their homes from flooding (*Colonias* = 3.12; *Urban* = 2.58), job disruption (*Colonias* = 2.79; *Urban* = 2.50), and casualties in their community (*Colonias* = 2.64; *Urban* = 2.67) to be only moderately to minimally likely. Damage to their homes from storm surge (*Colonias* = 2.65; *Urban* = 2.13) and injury to self and family (*Colonias* = 2.34; *Urban* = 2.01) were judged to be rather unlikely. Overall, the two groups of respondents were relatively similar in their expectations of hurricane impacts, although the colonias residents tended to have greater expectations of negative impacts—especially damage from storm surge and inland flooding.

Figure 8: Evacuees' Expected Accommodations (%)

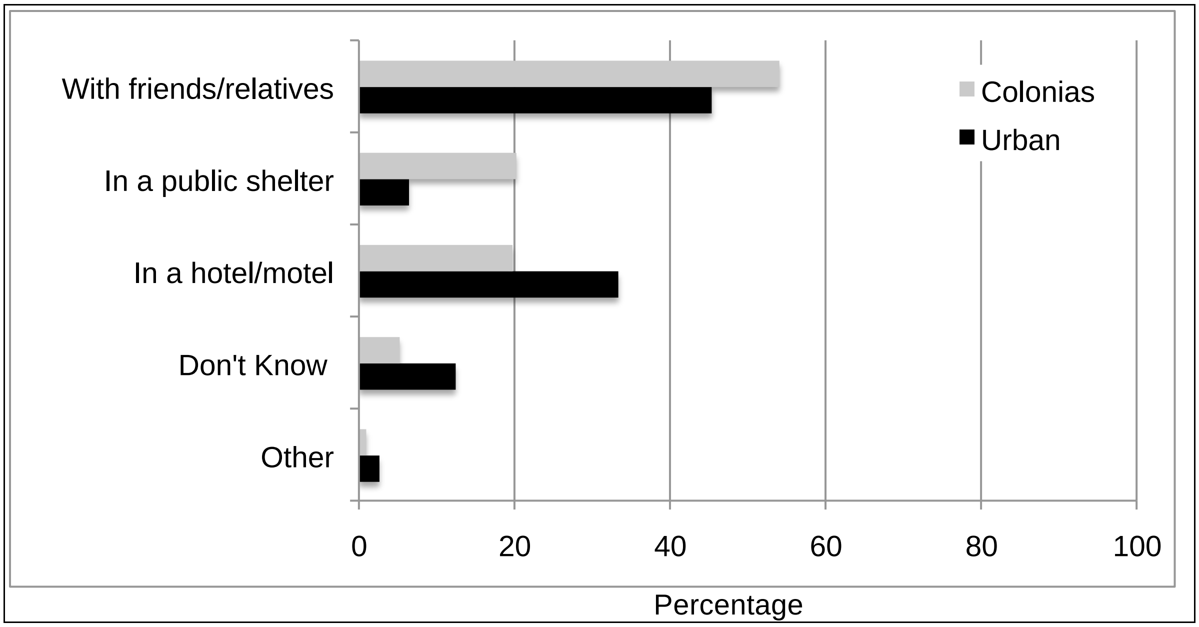
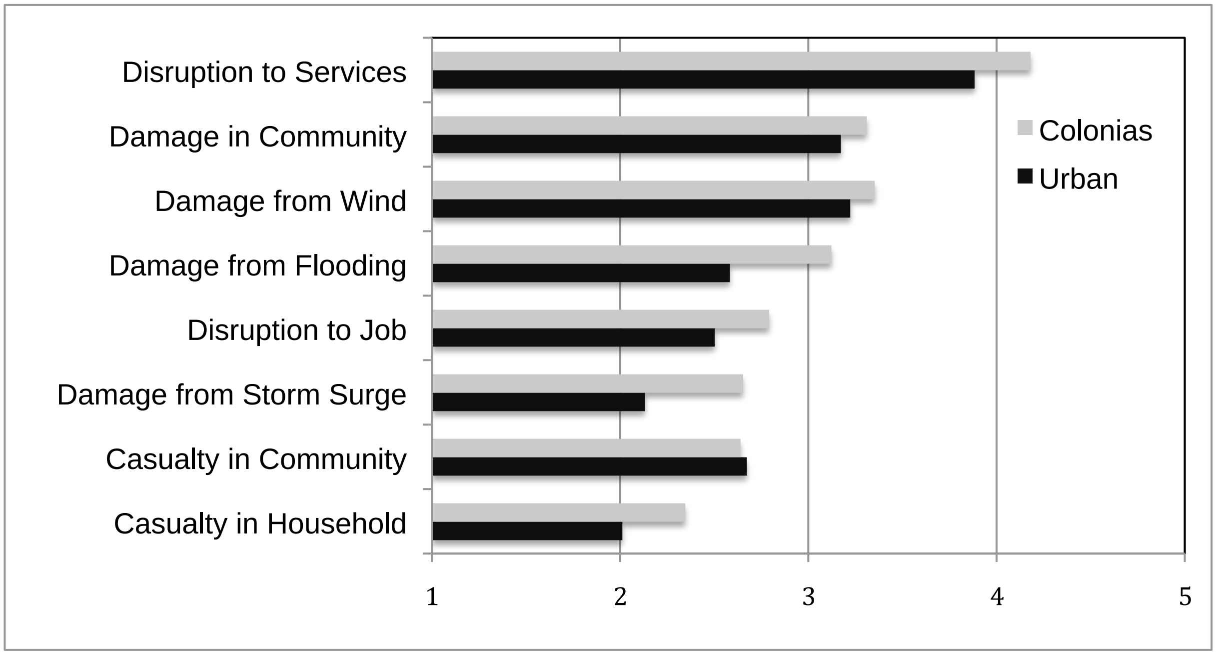


Figure 9. Expected Hurricane Impacts in the Next Five Years



Household Emergency Preparedness

Respondents were asked to report whether they had emergency preparedness measures such as a battery powered radio with spare battery, at least 4 gallons of water, 4 days of dried or canned food, a first-aid kit, a flashlight with spare batteries, window protections (e.g., shutters), sandbags, a gas-powered electric generator, an emergency plan, and flood insurance for their homes. As Table 7 indicates, more urban residents reported that they had a flashlight (*Colonias* = 64.9%; *Urban* = 90.0%) or battery-powered radio with spare battery (*Colonias* = 78.9; *Urban* = 70.2%), but more colonias residents reported storing water (*Colonias* = 84.3%; *Urban* =76.2%), and food at home (*Colonias* = 85.7%; *Urban* = 74.0%).

Table 7. Household Emergency Preparedness (%)

Items	Urban	Colonias	Average
Flashlight with spare battery	90.9	64.9	86.8
Battery power radio with spare battery	78.9	70.2	77.5
At least 4 gallons of water	76.2	84.3	77.5
Food	74.0	85.7	75.8
Kit	68.0	64.9	67.5
Window protections	67.9	64.3	67.3
Emergency plan	48.1	46.8	47.9
Flood insurance	38.3	20.8	35.6
Sandbag	33.7	45.0	35.5
Gas powered electric generator	25.6	20.1	24.7

There were approximately equal percentages in both groups who reported having first-aid kits (*Colonias* = 64.9%; *Urban* = 68.0%) and window protections (*Colonias* = 64.3%; *Urban* = 67.9%). Less than half of the respondents reported having an emergency plan (*Colonias* = 46.8%; *Urban* = 48.1%) and even smaller percentages reported having flood insurance (*Colonias* = 20.8%; *Urban* = 38.3%), sandbags (*Colonias* = 45.0%; *Urban* = 33.7%) or an electric generator (*Colonias* = 20.1%; *Urban* = 25.6%). On average, Urban residents reported slightly more preparedness measures (6.0) than the Colonias residents (5.7).

Structural Flood Mitigation Measures

Respondents were asked to identify whether their homes were elevated so water would pass under them, dry floodproofed so water cannot get in, or wet floodproofed area that water can get in but equipment such as washers, dryers, air conditioners and heaters are protected from the water. As Table 8 indicates, 35.9% of the urban residents and 49.5% of the colonias residents reported that their homes were elevated above the flood threat and many (*Colonias* = 45.0%; *Urban* = 24.4%) of respondents reported their homes were wet floodproofed, but only a relative minority of the respondents reported their homes were dry floodproofed (*Colonias* = 20.8%; *Urban* = 21.8%). It is notable that consistently larger percentages of colonias residents than urban residents reported implementation of the structural flood mitigation measures.

Table 8. Respondents' Flood Mitigation Measures (%)

Households' location	Urban	Colonias	Average
Elevated	35.9	49.5	38.0
Wet floodproofed	24.4	40.5	26.9
Dry floodproofed	21.8	27.7	22.7

Risk Area Identification

The survey asked respondents to report whether their homes were located in a hurricane risk area or a FEMA flood zone. There were 74.1% of the urban respondents' and 75.6% of the colonias respondents who reported that their homes were located in hurricane risk areas. In addition, 55.1% of the urban respondents' and 67.0% of the colonias respondents reported they were in FEMA flood zones. As shown in Table 9, 90.2% of the urban residents in hurricane risk areas accurately identified their hurricane risk, but 50.0% of the urban residents of the Inland Area overestimated their hurricane risk. That is, 50.0% of the inland residents thought they were in a hurricane risk area when the correct percentage should have been 0.0%. Moreover, 88.4% of the colonias residents in hurricane risk areas accurately identified their hurricane risk, but 65.9% of the colonias residents of the Inland Area (instead of 0.0%) thought they were in hurricane risk areas. The consistency of this pattern of people from inland areas believing that they are inside the hurricane risk areas is important because it confirms the data from Tables 4a and 4b in predicting an excessive level of evacuation from inland areas as a hurricane approaches VSA.

Table 9. Respondents' Risk Area Accuracy (%)

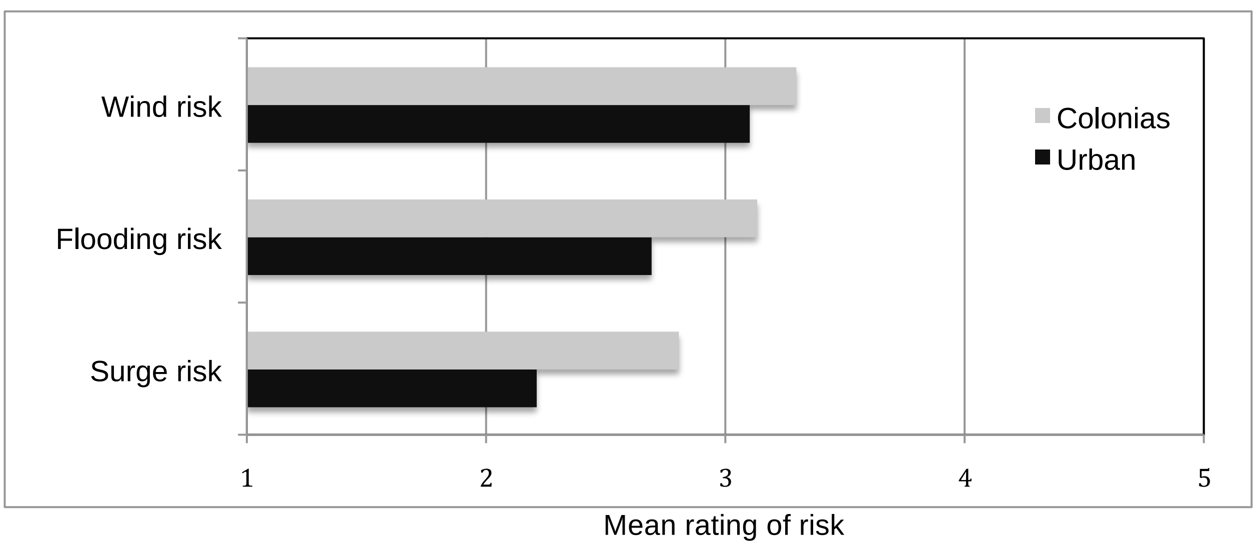
Actual Location		Households' self-report Risk Area	Inland Area	Total
Urban	Inland Area	50.0 (49)	50.0 (49)	98
	Risk Area	90.2 (119)	9.8 (13)	132
Colonias	Inland Area	65.9 (83)	34.1 (43)	126
	Risk Area	88.4 (84)	11.6 (11)	95

Perceived Structural Vulnerability to Hurricane Threats

Respondents were asked to report their perceptions of the vulnerability of their homes to three different hurricane threats—storm wind, storm surge, or inland flooding—on a scale from 1-5 (where 1 = *not at all likely* and 5 = *almost certain*). As Figure 10 indicates, respondents reported a moderate level of concern about storm wind risk (*Colonias* = 3.29; *Urban* = 3.10), followed by inland flooding risk (*Colonias* = 3.13; *Urban* = 2.69) and storm surge (*Colonias* = 2.80; *Urban* = 2.21). Colonias residents had consistently higher perceptions of all three threats, but the differences were larger for surge and inland flooding than for wind risk.

There were no statistically significant differences in perceptions of wind risk ($F_{5,237} = .60$, *ns*) and storm surge risk ($F_{5,224} = 1.62$, *ns*) among the hurricane risk areas. However, respondents' risk perceptions for inland flood risk were significantly different ($F_{5,226} = 2.44$, $p < .05$) among hurricane risk areas. Unsurprisingly, those whose houses were close to the coast were more concerned about surge flooding risk than those who lived far from the coast.

Figure 10: Respondents' Risk Perceptions



ANALYSIS

To generate estimates of the likely response of VSA residents to approaching hurricanes, it is necessary to combine the results from the urban and colonias samples by weighting them in proportion to the frequency of these two groups in the overall population of their counties. As Table 9 indicates, colonias residents are 11.5% of the population of Cameron County, 15.7% of the population of Willacy County, and 17.9% of the population of Hidalgo County. Since Cameron and Willacy Counties both have the same types of hurricane risk areas (Risk Area 1-5), we calculated weighted average percentages of urban and colonias residents in Cameron and Willacy counties combined to produce the forecasts for those two counties in Tables 10 and 11. Because Hidalgo County does not have any hurricane risk areas, we calculated percentages of urban and colonias residents to produce the forecasts for county alone in Table 12.

Table 9. Respondents' Risk Area Accuracy (%)

	Total Population	Total Colonias	Urban %	Colonias %
Cameron	406220	46842	88.5	11.5
Willacy	22134	3465	84.3	15.7
Hidalgo	774769	138458	82.1	17.9
Total	1203123	188765		

Objective 1

This objective is to estimate the number of evacuees and evacuating vehicles within the three county study area under various Tropical Storm/hurricane scenarios—e.g. Tropical Storm, and Category 1-5 hurricanes). Accordingly, the first two rows of Tables 10a (Cameron County) and 10b (Willacy County) show, for each location (Barrier Island, Risk Area 1&2, Risk Area 3, Risk Area 4&5, and the inland portion of the county), the estimated population and the estimated number of households (calculated by dividing the estimated population of each area by the average household size that the 2010 census reported for that county). Each successive block of three rows shows, for each storm category, the estimated evacuation rate (from Table 4c), the estimated number of evacuees, and the estimated number of evacuating vehicles for each of the five locations. Table 10c displays the corresponding data for Hidalgo County. It is important to recognize that the number of evacuees and evacuating vehicles in the first five columns is the estimate for that area alone. For example, the estimates of 254,393 evacuees and 119,869 evacuating vehicles from Cameron County RA 4&5 for a Category 5 hurricane is for those risk areas only. The *total* number of evacuees and evacuating vehicles from Cameron County for a Category 5 hurricane can be found in the last column (County Total).

Table 10a. Estimated Number of Evacuees and Evacuating Vehicles for Cameron County

	Barrier Island	RA 1&2	RA 3	RA 4&5	Inland	County Total
Population	2816	12,585	19,620	264,167	106,138	
Households	829	3,706	5,778	77,797	31,257	
Evacuation rate-TS	50.0	16.8	20.0	19.0	12.8	
Number of evacuees-TS	1,408	2,114	3,924	50,192	13,586	71,224
Number of vehicles-TS	663	996	1,849	23,650	6,402	33,560
Evacuation rate-C1	75.0	52.4	40.0	29.2	30.3	
Number of evacuees-C1	2,112	6,595	7,848	77,137	32,160	125,851
Number of vehicles-C1	995	3,107	3,698	36,347	15,154	59,301
Evacuation rate-C2	100.0	78.3	66.7	50.2	61.0	
Number of evacuees-2	2,816	9,854	13,087	132,612	64,744	223,113
Number of vehicles-C2	1,327	4,643	6,166	62,486	30,507	105,130
Evacuation rate-C3	100.0	100.0	80.0	76.4	81.4	
Number of evacuees-C3	2,816	12,585	15,696	201,824	86,396	319,317
Number of vehicles-C3	1,327	5,930	7,396	95,099	40,710	150,461
Evacuation rate-C4	100.0	100.0	80.0	91.0	90.9	
Number of evacuees-C4	2,816	12,585	15,696	240,392	96,479	367,968
Number of vehicles-C4	1,327	5,930	7,396	113,272	45,461	173,386
Evacuation rate-C5	100.0	100.0	80.0	96.3	91.7	
Number of evacuees-C5	2,816	12,585	15,696	254,393	97,329	382,818
Number of vehicles-C5	1,327	5,930	7,396	119,869	45,861	180,383

Table 10b. Estimated Number of Evacuees and Evacuating Vehicles for Willacy County

	RA 1&2	RA 3	RA 4&5	Inland	County Total
Population	192	34	19,381	2,679	
Households	50	9	5,048	698	
Evacuation rate-TS	16.8	20.0	19.0	12.8	
Number of evacuees-TS	32	7	3,682	343	4,064
Number of vehicles-TS	13	3	1,535	143	1,694
Evacuation rate-C1	52.4	40.0	29.2	30.3	
Number of evacuees-C1	101	14	5,659	812	6,585
Number of vehicles-C1	42	6	2,358	338	2,744
Evacuation rate-C2	78.3	66.7	50.2	61.0	
Number of evacuees-C2	150	23	9,729	1,634	11,536
Number of vehicles-C2	63	9	4,054	681	4,807
Evacuation rate-C3	100.0	80.0	76.4	81.4	
Number of evacuees-C3	192	27	14,807	2,181	17,207
Number of vehicles-C3	80	11	6,170	909	7,170
Evacuation rate-C4	100.0	80.0	91.0	90.9	
Number of evacuees-C4	192	27	17,637	2,435	20,291
Number of vehicles-C4	80	11	7,350	1,015	8,456
Evacuation rate-C5	100.0	80.0	96.3	91.7	
Number of evacuees-C5	192	27	18,664	2,457	21,340
Number of vehicles-C5	80	11	7,778	1,024	8,893

Table 10c. Estimated Number of Evacuees and Evacuating Vehicles for Hidalgo County

	East	West	500 year Floodplain	County Total
Population	84,349	165,343	523,622	
Households	27031	52987	167803	
Evacuation rate-TS	40.6	14.7	13.5	
Number of evacuees-TS	34,246	24,305	70,689	129,240
Number of vehicles-TS	17,559	12,462	36,245	66,267
Evacuation rate-C1	52	33	32.8	
Number of evacuees-C1	43,861	54,563	171,748	270,173
Number of vehicles-C1	22,490	27,977	88,063	138,530
Evacuation rate-C2	78.9	58.7	56.8	
Number of evacuees-2	66,551	97,056	297,417	461,025
Number of vehicles-C2	34,124	49,765	152,499	236,388
Evacuation rate-C3	98.4	81.1	82.3	
Number of evacuees-C3	82,999	134,093	430,941	648,033
Number of vehicles-C3	42,558	68,756	220,963	332,276
Evacuation rate-C4	98.4	92.6	92.4	
Number of evacuees-C4	82,999	153,108	483,827	719,934
Number of vehicles-C4	42,558	78,505	248,080	369,143
Evacuation rate-C5	98.4	95.7	93.7	
Number of evacuees-C5	82,999	158,233	490,634	731,866
Number of vehicles-C5	42,558	81,133	251,570	375,261

Objective 2

This objective is to identify the popularity of different evacuee destinations and the locations where evacuees plan to seek accommodations. Table 11, which shows the expected evacuation destinations of VSA residents by county, was constructed by multiplying the overall proportions of VSA residents expecting to travel to each of the seven principal evacuation destinations (taken from Table 5c) by the number of evacuating vehicles expected at each storm category. The overall proportions were used rather than the county-specific proportions because the latter did not differ from each other significantly and the pooled proportion can be expected to be more stable statistically.

Table 11. VSA Residents' Expected Evacuation Destinations, by County

Destination City		San Antonio	Houston	Austin	Laredo	Dallas	McAllen	Mexico
Destination Proportion		.470	.098	.101	.099	.042	.048	.060
Origin Cameron								
Category	Evacuating Vehicles							
TS	33,560	15,773	3,289	3,390	3,322	1,410	1,611	2,014
C1	59,301	27,871	5,811	5,989	5,871	2,491	2,846	3,558
C2	105,130	49,411	10,303	10,618	10,408	4,415	5,046	6,308
C3	150,461	70,717	14,745	15,197	14,896	6,319	7,222	9,028
C4	173,386	81,491	16,992	17,512	17,165	7,282	8,323	10,403
C5	180,383	84,780	17,678	18,219	17,858	7,576	8,658	10,823
Origin Willacy								
Category	Evacuating Vehicles							
TS	1,455	684	143	147	144	61	70	87
C1	2,321	1,091	227	234	230	97	111	139
C2	4,061	1,909	398	410	402	171	195	244
C3	6,089	2,862	597	615	603	256	292	365
C4	7,205	3,386	706	728	713	303	346	432
C5	7,589	3,567	744	766	751	319	364	455
Origin Hidalgo								
Category	Evacuating Vehicles							
TS	66,267	31,145	6,494	6,693	6,560	2,783	3,181	3,976
C1	138,530	65,109	13,576	13,992	13,714	5,818	6,649	8,312
C2	236,388	111,102	23,166	23,875	23,402	9,928	11,347	14,183
C3	332,276	156,170	32,563	33,560	32,895	13,956	15,949	19,937
C4	369,143	173,497	36,176	37,283	36,545	15,504	17,719	22,149
C5	375,261	176,373	36,776	37,901	37,151	15,761	18,013	22,516

Table 12, which shows the expected evacuation routes of VSA residents by county, was constructed by multiplying the overall proportions of VSA residents expecting to travel on each of the seven principal evacuation routes (taken from Table 6c) by the number of evacuating vehicles expected at each storm category.

Table 12. VSA Residents' Expected Evacuation Routes, by County

Category	Evacuating Vehicles	US-77	US-281	US-83	I-37	I-35	SH-100	SH-186
Cameron								
Evacuation Route		US-77	US-281	US-83	I-37	I-35	SH-100	SH-186
Route Proportion		.675	.207	.347	.155	.081	.132	0
TS	33,560	22,653	6,947	11,645	5,202	2,718	4,430	-
C1	59,301	40,028	12,275	20,577	9,192	4,803	7,828	-
C2	105,130	70,963	21,762	36,480	16,295	8,516	13,877	-
C3	150,461	101,561	31,145	52,210	23,321	12,187	19,861	-
C4	173,386	117,036	35,891	60,165	26,875	14,044	22,887	-
C5	180,383	121,759	37,339	62,593	27,959	14,611	23,811	-
Willacy								
Evacuation Route		US-77	US-281	US-83	I-37	I-35	SH-100	SH-186
Route Proportion		.634	.494	.105	.053	.137	0	.167
TS	1,455	922	719	153	77	199	-	243
C1	2,321	1,472	1,147	244	123	318	-	388
C2	4,061	2,575	2,006	426	215	556	-	678
C3	6,089	3,860	3,008	639	323	834	-	1,017
C4	7,205	4,568	3,559	757	382	987	-	1,203
C5	7,589	4,811	3,749	797	402	1,040	-	1,267
Hidalgo								
Evacuation Route		US-77	US-281	US-83	I-37	I-35	SH-100	SH-186
Route Proportion		.132	.56	.299	.055	.055	0	0
TS	66,267	8,747	37,110	19,814	3,645	3,645	-	-
C1	138,530	18,286	77,577	41,420	7,619	7,619	-	-
C2	236,388	31,203	132,377	70,680	13,001	13,001	-	-
C3	332,276	43,860	186,075	99,351	18,275	18,275	-	-
C4	369,143	48,727	206,720	110,374	20,303	20,303	-	-
C5	375,261	49,534	210,146	112,203	20,639	20,639	-	-

To estimate the demand for space in *commercial facilities within VSA*, we began by assuming that each evacuating household would occupy one room. We then multiplied the total number of evacuating households in each of the three counties by the percentage of the population evacuating to Inland VSA (12.5%) to obtain an estimate of the number of households evacuating to VSA. Next, we multiplied this number by the weighted average percentage of the evacuees expecting to go to commercial facilities (30.9%). The resulting estimates of the number of rooms required for each county's evacuees in each of the six storm categories is displayed in Table 15.

To estimate the demand for space in *public shelters within VSA*, we multiplied the estimated number of evacuating persons by the percentage of the population evacuating to Inland VSA

(12.5%) to obtain an estimate of the number of persons evacuating to VSA. Next, we multiplied this number by the weighted average percentage of the evacuees expecting to go to public shelters (8.9%). The resulting estimates of the number of beds required for each county's evacuees in each of the six storm categories is also displayed in Table 13.

Table 13. Estimated Number of Commercial Rooms and Public Shelter Beds for all VSA Counties

	Cameron		Willacy		Hidalgo		VSA Total	
	Hotel rooms	Public Shelter beds	Hotel room s	Public Shelter beds	Hotel rooms	Public Shelter beds	Hotel rooms	Public Shelter beds
Tropical Storm	6,481	6,339	281	311	12,798	11,502	19,560	18,152
Category 1	11,452	11,201	448	496	26,754	24,045	38,654	35,742
Category 2	20,303	19,857	784	867	45,653	41,031	66,740	61,755
Category 3	29,058	28,419	1,176	1,301	64,171	57,675	94,405	87,395
Category 4	33,485	32,749	1,391	1,539	71,291	64,074	106,167	98,362
Category 5	34,836	34,071	1,466	1,621	72,472	65,136	108,774	100,828

Objective 3

This objective is to determine the general level of awareness, hurricane experience, and evacuation experience of the vulnerable population and how this experience may affect the decision to evacuate. As previously noted in Table 2, the majority of households have hurricane experience (*Colonias* = 62.8%; *Urban* = 60.0%). Among those with hurricane experience, there is only a negligible difference in the percentage of those who did evacuate and were hit (63.2%) and those who stayed and were hit (68.9%). As the three right-hand columns in Table 14a indicate, there are only small nonsignificant differences among the five experience groups (stay and hit, stay and miss, evacuate and hit, evacuate and miss, never hit) in evacuation expectations for major hurricanes (Categories 3-5). However, there are statistically significant differences among the experience groups in evacuation expectations for minor hurricanes (Categories 1 and 2). For Tropical Storms and Category 1 hurricanes, those who had previously evacuated (whether or not the storm hit) are quite different from those who had previously stayed (whether or not the storm hit). Those with no hurricane experience are quite similar to those who had stayed. For Tropical Storms, only those who had previously evacuated and the storm missed were very likely to evacuate.

Table 14a. Hurricane Evacuation Experience by Evacuation Expectations (Urban)

Hurricane Experience	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Inexperienced	15.9	26.2	52.3	83.5	91.8	93.7
Stayed but hit	9.6	20.0	53.9	80.8	94.6	94.5
Stayed and miss	11.4	32.4	50.0	75.8	84.8	87.5
Evacuated and hit	21.1	60.0	76.2	85.7	94.7	94.1
Evacuated but miss	57.1	64.3	84.6	85.7	92.9	100.0
	χ_4^2 = 20.6 p < .001	χ_4^2 = 20.5 p < .001	χ_4^2 = 8.9 p > .05	χ_4^2 = 1.4 p > .05	χ_4^2 = 3.2 p > .05	χ_4^2 = 20.6 p > .05

The three right-hand columns in Table 14b reveal a pattern that is somewhat similar to that for major hurricanes (Categories 3-5) in Table 16a, although the *Stay but hit* group consistently had somewhat lower evacuation expectations than the other experience groups. There are large and statistically significant differences among the five experience groups in evacuation expectations as storm intensity increases from Category 1 through Category 5.

Table 14b. Hurricane Evacuation Experience by Evacuation Expectations (Colonias)

Hurricane Experience	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Inexperienced	39.3	57.3	78.7	92.2	96.7	96.7
Stayed but hit	20.0	32.3	45.5	69.2	83.1	86.2
Stayed and miss	27.3	59.1	72.7	90.5	95.2	95.2
Evacuated and hit	36.7	66.7	86.7	93.3	100.0	100.0
Evacuated but miss	42.9	85.7	86.7	92.9	100.0	100.0
	χ_4^2 = 7.7 p > .05	χ_4^2 = 20.4 p < .001	χ_4^2 = 28.0 p < .001	χ_4^2 = 19.6 p < .001	χ_4^2 = 15.5 p = .004	χ_4^2 = 11.3 p = .024

Table 14c shows the crosstabulation of hurricane evacuation experience and evacuation expectations for the combined sample (weighted by the proportions of urban and colonias residents). As is the case for the previous two tables, the percentage of respondents expecting to evacuate increases in each of the five experience groups from a Tropical Storm to a Category 5 hurricane. Moreover, these groups have similar levels of evacuation expectations for the major hurricanes. However, there are notable differences among experience groups for a Tropical Storm and the minor hurricanes. The general pattern here is for those who evacuated (whether or not the storm hit) to be much more likely to evacuate than those who stayed in a previous hurricane (whether or not the storm hit), with the inexperienced (never hit) respondents falling between those who did and those who did not evacuate.

Table 14c. Hurricane Evacuation Experience by Evacuation Expectations (Combined)

Hurricane Experience	Tropical Storm	Category 1	Category 2	Category 3	Category 4	Category 5
Inexperienced	19.6	31.1	56.4	84.9	92.6	94.2
Stayed but hit	11.2	21.9	52.6	79.0	92.8	93.2
Stayed and miss	13.9	36.6	53.6	78.1	86.4	88.7
Evacuated and hit	23.5	61.1	77.8	86.9	95.5	95.0
Evacuated but miss	54.9	67.7	84.9	86.8	94.0	100.0

Objective 4

This objective is to determine the significant factors influencing the population's decisions to evacuate or stay (e.g., local officials, personal resources, border security checkpoints, social influences, media, job, etc.). To address this objective, we computed the correlations among the variables in the questionnaire. A correlation coefficient, which is designated by the symbol *r*, is a measure of the degree to which two variables are related to each other. A correlation s coefficient falls in the range between -1.0 and + 1.0, with $r = +1$ when there is a perfect positive relationship between *X* and *Y*, $r = –1$ when there is a perfect negative (inverse) relationship between *X* and *Y*, and $r = 0$ when there is a no relationship between *X* and *Y*. Once we have calculated a single correlation coefficient, we can enter it into a correlation matrix that contains the correlations among all the variables we have measured. The first column of Table 15 lists the number of each variable in the correlation matrix from 1-53 and the second column lists those variables' item numbers along with a short label describing what that variable measures. For example, variable Number 1 in the correlation matrix is Q16 (respondent sex) from the questionnaire in Appendix A. Variables 25, 26, 36, 37, 39, 40, 43, and 51 in the correlation matrix do not have item numbers because they are the means (arithmetic averages) of multiple items from the questionnaire. Specifically, *EmerPrep* was computed by taking the average of Items Q13a-Q13j from the questionnaire to produce an overall measure of emergency preparedness. Similarly, *StrMit* is the mean of the structural mitigation items (Q14a-Q14c), *TrafficImped* is the mean of the traffic impediments items (Q4a-Q4b), *EconImped* is the mean of the economic impediments items (Q4c-Q4f), *ComImp* is the mean of the community impact items (Q12a-Q12b), *PerImp* is the mean of the personal impact items (Q12c-Q12f), and *PerVul* is the mean of the personal vulnerability items (Q26a-Q26c). However, *VehEquiv* is the *sum* of the evacuating vehicles items (Q7a-Q7c).

The third column of Table 15 displays the means of each of the variables and the fourth column of Table 15 displays the standard deviations (a measure of the variation of the individual scores around the mean) of each of the variables. The fifth through the 57th columns of the matrix contain the correlations between each pair of variables. For example, the correlation between Variable 1 (Q16_Age) and Variable 2 (Q_17Gender) can be found by looking in the column labeled “1” (for Variable 1) and scanning down to the second row (“Number 2, Q_17Gender”), which indicates that the correlation between these two variables is r = -.08. This correlation is not significantly different from zero (i.e., there is essentially no association between the two variables), so it is not highlighted. However, the correlation between Variable 1 (Q16_Age) and Variable 3 (Q_18Hispanic) is r = -.25 and that correlation is highlighted because it is statistically significantly different from zero. There are many blank cells in the correlation matrix because those cells don’t provide useful information. Row 1 Column 1 is blank because the correlation of any variable with itself is always 1.0. Thus, any cell in which the row number equals the column number (Row 2, Column 2; Row 3, Column 3; etc.—which is called the *main diagonal* of the correlation matrix) is blank. Moreover, a correlation matrix is *symmetric* because the correlation for Row 1, Column 2 is identical to the correlation for Row 2, Column 1. Thus, because the order in which the variables are listed has no effect on the correlation between those two variables, we leave those cells blank also.

As indicated by the correlations of Items 36-38 in Table 15, expectations of evacuation inhibitors (i.e., traffic inhibitors, economic inhibitors, and border checkpoints) had positive correlations with evacuation expectations but none of them were statistically significant. However, respondents with household members who would need special medical assistance in evacuating were significantly more likely to evacuate from a Tropical Storm and marginally (but not significantly) more likely to evacuate from Category 1 and 2 storms. By contrast, those with pets were significantly less likely to evacuate from a Category 1 storm and marginally (but not significantly) less likely to evacuate from a Tropical Storm or a Category 2 storm. As a practical matter, emergency managers should presume that those with medical needs are slightly more likely and those with pets are slightly less likely to evacuate from minor storms. The percentage of households needing medical assistance is relatively small (17%) whereas the percentage of households with pets is quite large (48%), so the net effect of these two variables would be a slight decrease in the percentage of households evacuating from minor storms.

Table 15 also shows that four information sources are likely to affect the likelihood of household evacuations. Examination of the correlations of Items 27-35 (Items 2a-i in the questionnaire) shows that those who expect to rely on the National Hurricane Center (Item 27) are clearly more likely to evacuate from all three categories of major storms. Similarly, those who expect to rely on local TV and radio (Items 29 and 30) are marginally more likely to evacuate from major storms. By contrast, those who expect to rely on peers (Item 35) are marginally more likely to evacuate from *minor* storms.

Only three demographic variables were related to evacuation expectations. Respondents with higher levels of education and income (which were correlated r = .58) were less likely to evacuate from minor storms, as were those with a larger number of registered vehicles (which was correlated r = .18 with education and r = .28 with income). The practical implication of the latter result is that, because the number of vehicles taken during evacuation is related to the number of registered vehicles, the number of vehicles taken during minor storms is likely to be slightly lower than would otherwise be expected from the data in Table 15.

Table 15 also indicates that two types of experience are related to respondents' expectations of evacuation from approaching storms. First, those who stayed and were hit by a previous hurricane (Item 20) are slightly less likely to evacuate from minor storms, whereas those who evacuated and were missed by a previous hurricane (Item 23) are slightly more likely to evacuate from minor storms.

In addition, expected personal damage and casualties (Item 40 in Table 15, which consisted of Items 12c-12f in the questionnaire) had positive correlations with evacuation expectations for the minor hurricanes (Categories 1 and 2). Similarly, perceived personal vulnerability (Items 26a-c in the questionnaire) also had had positive correlations with evacuation expectations for the minor hurricanes. Although perceived vulnerability was lower for those who reported having structural mitigation (Items 14a-c in the questionnaire), structural mitigation was positively correlated only with expectations of evacuating for a Tropical Storm and not significantly correlated with any of the categories of hurricane.

Objective 5

This objective is to identify the timeframe and how the threatened population will evacuate in response to official evacuation orders and various defined forecast storm conditions such as category of hurricane, and potential flooding. As indicated in Table 4c, the percentage of Cameron and Willacy County residents evacuating from an approaching hurricane steadily increases with storm intensity (Tropical Storm through Category 5) and proximity to the coast, with Barrier Island residents having the highest likelihood of evacuation for any given storm category. In addition, Table 4f shows the percentage of Hidalgo County residents evacuating from an approaching hurricane also increases with storm intensity (Tropical Storm through Category 5) and proximity to the coast, with Hidalgo East residents having a higher likelihood of evacuation than Hidalgo West residents for all storm categories except Categories 4 and 5. Hidalgo floodplain residents, who generally live along the Rio Grande River, have as high a likelihood of evacuation as Hidalgo West residents.

Table 15. Means, Standard Deviations, and Intercorrelations Among Variables.

Number	Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Q16_Age	53.51	15.60															
2	Q17_Gender	.56	.50	-.08														
3	Q18_Hispanic	.85	.35	-.25	.13													
4	Q19_White	.97	.16	.04	.11	.04												
5	Q20_Marital	.70	.46	-.11	-.25	.01	-.06											
6	Q21_Edu	12.51	2.73	-.10	-.01	-.23	.01	-.02										
7	Q22_Inc	28423.67	15791.24	-.04	-.12	-.24	.03	.19	.58									
8	Q23_HHSize	3.42	1.76	-.48	.09	.25	.01	.19	-.07	-.04								
9	Q23_Kids	1.00	1.27	-.50	.14	.19	-.01	.04	-.09	-.08	.77							
10	Q24_Ownership	.89	.31	.16	.00	-.05	.02	.03	.14	.18	-.08	-.14						
11	Q25_SF	.76	.42	.07	.03	.08	.03	.02	-.11	-.01	-.04	-.07	.00					
12	Q25_MF12	.11	.31	-.07	-.01	.01	.02	-.03	.13	.06	.11	.06	.03	-.63				
13	Q25_MF34	.00	.06	.06	-.07	-.07	.01	.04	.11	.11	-.07	-.05	.02	-.12	-.02			
14	Q25_MH	.09	.28	-.11	-.05	-.07	-.09	.04	-.03	-.10	.02	.09	-.04	-.55	-.11	-.02		
15	Q6_RegVeh	2.12	1.05	-.18	-.11	.11	.05	.20	.18	.28	.31	.03	.16	-.03	.10	-.04	-.05	
16	Q5a_MedAssist	.17	.35	.17	.03	.08	.00	-.07	-.13	-.16	-.09	-.11	-.03	.07	-.10	-.03	.03	-.17
17	Q5b_Pets	.48	.47	-.09	.04	-.04	-.01	.02	.09	.05	.13	.04	.10	.04	.03	-.07	-.05	.15
18	Q15a_HurrRisk	.75	.43	.19	-.09	-.10	-.06	.02	.03	.03	-.11	-.15	-.02	-.02	-.01	.04	.07	-.01
19	Q15b_FloodRisk	.61	.46	.10	.04	.01	-.04	-.06	-.10	-.16	-.03	-.08	.03	.03	-.04	.03	.02	-.04
20	Q1a_StayHit	.31	.46	.10	.01	-.03	-.11	-.01	-.04	.06	-.07	-.04	.02	.03	-.07	-.04	.04	.02
21	Q1b_StayMiss	.12	.33	-.07	-.09	-.01	.06	.07	.06	.02	.04	-.02	.09	-.03	.07	-.02	.00	.10
22	Q1c_EvacHit	.11	.32	.06	.07	-.01	.02	-.08	.04	-.03	-.03	-.02	-.03	-.07	.07	-.02	.03	-.05
23	Q1d_EvacMiss	.06	.24	.03	-.05	.01	.05	.00	.02	-.07	.04	.02	-.17	.06	-.03	.12	-.05	-.09
24	Q1e_NoExper	.39	.48	-.10	.03	.03	.03	.02	-.04	-.02	.03	.06	.02	.00	-.01	.01	-.02	-.01
25	EmerPrep	.64	.28	.20	-.16	-.02	.09	.00	-.03	.07	-.11	-.15	.07	.06	.02	-.03	-.17	.07
26	StrMit	.34	.35	-.06	.03	.09	.01	-.02	-.08	-.03	-.04	.01	.00	-.16	.04	.06	.17	-.02
27	Q2i_NatHurrCtr	4.22	1.18	-.02	.06	-.04	.07	.09	.15	.08	.11	.08	.09	-.03	.04	.04	-.02	.07
28	Q2a_NatTV	3.63	1.37	-.03	.01	.04	.08	.04	.05	.01	.04	.00	.06	.08	-.08	-.08	-.02	.06
29	Q2b_LocTV	4.35	.94	.01	.13	.09	.00	.05	-.01	-.01	.04	.00	.02	.04	-.06	-.16	.00	.10
30	Q2c_LocRad	3.69	1.37	-.05	.05	.09	-.02	-.01	-.02	-.10	.09	.09	.03	-.01	.04	-.10	-.01	.05
31	Q2d_LocPaper	2.47	1.35	-.05	-.01	.05	.06	-.05	.03	.04	.05	.02	.02	.03	-.04	-.07	.00	.08
32	Q2e_Internet	2.59	1.47	-.26	.07	.01	.07	.07	.21	.15	.21	.19	.08	-.05	.04	-.07	.00	.13
33	Q2f_SocMedia	2.09	1.33	-.28	.10	.13	.03	.03	.04	-.02	.23	.19	.05	.00	-.01	-.05	.04	.12
34	Q2g_LocOff	3.24	1.47	.05	.12	.08	.03	.05	.04	-.02	.03	.01	.03	.09	-.02	-.10	-.11	.07
35	Q2h_Peers	3.47	1.24	-.09	.10	.18	-.03	-.07	-.19	-.18	.04	.09	-.07	.05	-.03	.00	-.04	.00
36	TrafficImped	2.95	1.26	-.01	.05	.14	-.03	-.01	-.12	-.14	.01	-.02	.01	.01	-.01	.02	.01	-.03
37	EconImped	2.96	1.16	-.06	.01	.13	-.06	-.03	-.14	-.14	.08	.05	-.04	.06	.00	-.09	-.07	.07
38	Q4g_Chkpoints	1.86	1.25	-.05	-.01	.07	.04	.01	-.18	-.15	.16	.08	.00	-.08	.07	-.02	.04	.05

Table 15. Means, Standard Deviations, and Intercorrelations Among Variables (continued).

Number	Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39	ComImp	2.96	1.03	.06	.02	.04	.00	-.04	-.09	-.13	.05	.03	-.08	-.04	.00	-.06	.06	-.06
40	PerImp	2.71	1.03	.05	.06	.16	-.09	.00	-.28	-.30	.07	.05	-.15	.05	-.03	-.06	-.04	-.11
41	Q12g_jobDisrupt	2.64	1.42	-.13	.06	.14	.00	.03	-.17	-.20	.19	.13	-.10	-.03	.06	-.05	-.01	.05
42	Q12h_UtilDisrupt	4.02	1.10	.14	.06	-.02	-.02	.09	-.06	-.08	.00	-.07	.00	.01	.04	-.09	-.03	.02
43	PerVul	2.88	.98	-.03	.04	.15	.02	-.07	-.22	-.25	.05	.07	-.18	.05	-.11	-.09	.05	-.10
44	Q13j_FldInsur	.30	.45	.09	-.05	-.22	.09	.00	.23	.31	-.08	-.09	.13	-.08	.06	.10	-.02	.10
45	Q3a_TropStrm	.24	.41	.02	.05	.10	.00	.02	-.26	-.25	-.04	.03	-.01	.02	-.05	.04	-.01	-.20
46	Q3b_Cat1	.42	.48	.09	.06	.05	.06	.05	-.23	-.22	-.02	-.01	-.05	.02	-.06	.01	.04	-.17
47	Q3c_Cat2	.63	.47	.13	.05	-.03	-.02	.05	-.22	-.20	-.03	.03	-.03	-.01	-.10	.05	.12	-.18
48	Q3d_Cat3	.84	.36	.02	.05	-.10	-.03	-.03	-.05	-.04	-.04	.02	-.03	-.04	-.04	.03	.09	-.08
49	Q3e_Cat4	.93	.25	-.09	.02	-.07	-.04	.00	.08	.05	.10	.09	-.01	-.03	-.01	.02	.05	.00
50	Q3f_Cat5	.94	.23	-.09	.02	-.05	-.03	.01	.08	.07	.10	.06	.00	.00	-.03	.02	.04	.01
51	VehEquiv	1.58	.94	-.16	-.12	.02	.02	.13	.06	.10	.26	.03	.04	-.02	.10	-.07	-.04	.59
52	Q8_PublicTrans	.12	.24	.02	-.09	-.01	-.14	.00	-.04	-.07	-.02	-.03	-.07	-.02	-.04	-.02	.09	-.03
53	Q8_PeerTrans	.83	.28	-.03	.06	-.01	.10	.02	.04	.07	.06	.04	.05	.00	.02	.02	-.03	.07

Table 15. Means, Standard Deviations, and Intercorrelations Among Variables (continued).

Number	Variable	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1	Q16_Age																				
2	Q17_Gender																				
3	Q18_Hispanic																				
4	Q19_White																				
5	Q20_Marital																				
6	Q21_Edu																				
7	Q22_Inc																				
8	Q23_HHSize																				
9	Q23_Kids																				
10	Q24_Ownership																				
11	Q25_SF																				
12	Q25_MF12																				
13	Q25_MF34																				
14	Q25_MH																				
15	Q6_RegVeh																				
16	Q5a_MedAssist																				
17	Q5b_Pets	.04																			
18	Q15a_HurrRisk	.00	-.04																		
19	Q15b_FloodRisk	.05	-.09	.40																	
20	Q1a_StayHit	-.05	.01	.22	.11																
21	Q1b_StayMiss	.01	.02	-.05	-.01	-.25															
22	Q1c_EvacHit	.04	-.06	.05	.02	-.24	-.13														
23	Q1d_EvacMiss	.16	-.07	.02	-.01	-.18	-.10	-.09													
24	Q1e_NoExper	-.06	.04	-.22	-.10	-.53	-.30	-.29	-.21												
25	EmerPrep	-.07	.02	.07	.12	.02	.00	-.03	.03	-.01											
26	StrMit	.02	-.06	-.03	-.03	.11	-.02	-.01	-.09	-.04	.12										
27	Q2i_NatHurrCtr	-.01	.01	-.06	.01	-.18	.08	-.02	.09	.09	.15	-.18									
28	Q2a_NatTV	.01	.04	-.11	.02	-.06	.07	-.01	.04	.00	.12	-.12	.49								
29	Q2b_LocTV	.00	.04	-.06	-.03	-.05	-.09	.07	-.02	.07	.05	-.14	.42	.38							
30	Q2c_LocRad	.01	-.01	-.09	.05	-.11	.01	.00	.06	.07	.09	-.13	.47	.38	.46						
31	Q2d_LocPaper	.05	-.03	-.08	.01	-.05	-.01	.00	.05	.03	.11	-.11	.27	.28	.26	.41					
32	Q2e_Internet	.00	.06	-.05	-.03	-.03	.05	.02	.03	-.04	.03	-.03	.30	.25	.15	.25	.32				
33	Q2f_SocMedia	.01	.00	-.11	-.02	-.06	.06	.00	.03	.01	-.01	.01	.17	.13	.11	.16	.25	.60			
34	Q2g_LocOff	.00	.02	.02	-.03	-.04	-.02	.05	-.01	.02	.07	-.06	.22	.24	.19	.27	.42	.22	.24		
35	Q2h_Peers	.12	-.06	-.06	.05	.04	-.03	.07	-.02	-.05	.03	.03	.14	.09	.25	.22	.23	.12	.26	.30	
36	TrafficImped	.07	.01	-.01	.06	-.06	.02	-.07	.00	.09	.08	-.02	.21	.22	.13	.19	.13	.09	.08	.16	.14
37	EconImped	.01	.00	-.04	.08	-.09	.04	-.07	.02	.10	.07	-.08	.20	.23	.13	.25	.24	.16	.19	.18	.14
38	Q4g_Chkpoints	.12	.04	-.16	.00	-.13	.06	-.09	.01	.14	.00	.02	.06	.03	.07	.15	.14	.10	.16	.07	.06

Table 15. Means, Standard Deviations, and Intercorrelations Among Variables (continued).

Number	Variable	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
39	ComImp	.12	-.08	.19	.22	.07	-.01	.13	.06	-.17	.12	-.10	.18	.17	.14	.20	.14	.08	.05	.14	.16
40	PerImp	.17	-.08	.17	.27	.02	-.01	.09	.08	-.11	.10	-.10	.15	.20	.14	.18	.13	.04	.06	.11	.21
41	Q12g_jobDisrupt	.00	-.08	.12	.16	-.02	.04	.01	-.01	-.01	.03	-.07	.15	.13	.07	.17	.07	.07	.13	.14	.13
42	Q12h_UtilDisrupt	.08	.00	.21	.18	.08	-.02	.11	-.03	-.12	.09	-.08	.11	.02	.11	.01	-.03	-.02	.03	.06	.11
43	PerVul	.17	-.05	.17	.30	.04	-.04	.11	.04	-.11	-.01	-.17	.06	.20	.14	.15	.14	.04	.04	.12	.20
44	Q13j_FldInsur	.00	.05	.04	.02	.01	.05	.01	.02	-.05	.28	.01	.04	.09	-.09	-.03	-.02	.09	-.03	-.03	-.12
45	Q3a_TropStrm	.16	-.10	-.06	.07	-.15	-.06	.05	.15	.07	-.01	.18	-.07	-.08	-.02	-.03	-.03	-.05	.04	.02	.12
46	Q3b_Cat1	.12	-.16	-.02	.11	-.21	.01	.15	.17	.01	.01	.07	.07	.05	.08	.04	.00	-.02	.06	.08	.15
47	Q3c_Cat2	.13	-.14	-.02	.14	-.18	-.03	.14	.12	.05	.00	.09	.14	.10	.10	.10	.02	-.01	.02	.07	.17
48	Q3d_Cat3	.04	-.09	.04	.15	-.14	-.02	.06	.04	.09	-.01	-.03	.15	.08	.10	.15	.09	.03	-.01	.09	.11
49	Q3e_Cat4	-.03	-.02	.06	.07	-.08	-.05	.07	.04	.05	-.03	-.07	.15	.06	.12	.12	.07	.10	.08	.09	.11
50	Q3f_Cat5	-.03	.00	.05	.06	-.09	-.05	.06	.07	.05	.03	-.05	.16	.06	.15	.16	.06	.09	.07	.08	.09
51	VehEquiv	-.11	.08	.01	.02	.06	.10	-.05	-.09	-.04	.04	-.02	.07	.07	.06	.04	.07	.12	.13	.07	.07
52	Q8_PublicTrans	.01	-.02	.05	.03	.08	-.05	.02	-.04	-.04	.01	.02	.05	.03	.02	.03	.12	.07	.03	.12	.10
53	Q8_PeerTrans	-.04	.04	-.02	-.05	-.10	.04	.02	.03	.04	.00	-.03	-.03	-.05	-.02	-.05	-.11	-.07	-.04	-.10	-.11

Table 15. Means, Standard Deviations, and Intercorrelations Among Variables (continued).

Number	Variable	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
1	Q16_Age																	
2	Q17_Gender																	
3	Q18_Hispanic																	
4	Q19_White																	
5	Q20_Marital																	
6	Q21_Edu																	
7	Q22_Inc																	
8	Q23_HHSize																	
9	Q23_Kids																	
10	Q24_Ownership																	
11	Q25_SF																	
12	Q25_MF12																	
13	Q25_MF34																	
14	Q25_MH																	
15	Q6_RegVeh																	
16	Q5a_MedAssist																	
17	Q5b_Pets																	
18	Q15a_HurrRisk																	
19	Q15b_FloodRisk																	
20	Q1a_StayHit																	
21	Q1b_StayMiss																	
22	Q1c_EvacHit																	
23	Q1d_EvacMiss																	
24	Q1e_NoExper																	
25	EmerPrep																	
26	StrMit																	
27	Q2i_NatHurrCtr																	
28	Q2a_NatTV																	
29	Q2b_LocTV																	
30	Q2c_LocRad																	
31	Q2d_LocPaper																	
32	Q2e_Internet																	
33	Q2f_SocMedia																	
34	Q2g_LocOff																	
35	Q2h_Peers																	
36	TrafficImped																	
37	EconImped	.46																
38	Q4g_Chkpoints	.25	.35															

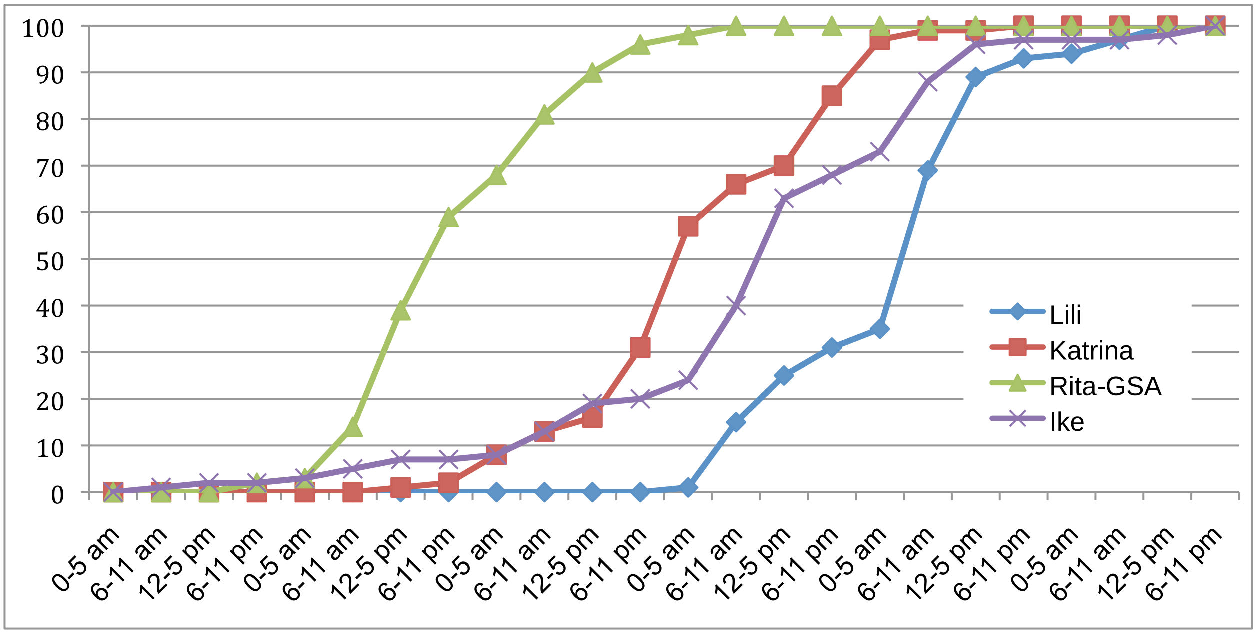
Table 15. Means, Standard Deviations, and Intercorrelations Among Variables (continued).

Number	Variable	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
39	ComImp	.23	.14	.03														
40	PerImp	.24	.21	.15	.64													
41	Q12g_jobDisrupt	.19	.27	.12	.36	.45												
42	Q12h_UtilDisrupt	.14	.04	-.01	.36	.43	.33											
43	PerVul	.10	.19	.01	.38	.57	.34	.23										
44	Q13j_FldInsur	-.07	-.03	-.03	-.04	-.11	-.03	-.01	-.06									
45	Q3a_TropStrm	.02	-.11	.08	-.03	.07	.02	-.04	.07	.00								
46	Q3b_Cat1	.03	-.07	.05	.05	.16	.11	.05	.16	-.01	.58							
47	Q3c_Cat2	.05	-.01	.04	.12	.23	.17	.10	.15	.00	.39	.63						
48	Q3d_Cat3	.02	-.01	.00	.13	.10	.14	.05	.10	.07	.22	.35	.55					
49	Q3e_Cat4	-.02	.02	-.04	.12	.08	.08	.04	.08	.03	.12	.22	.34	.64				
50	Q3f_Cat5	-.03	.00	.00	.12	.07	.08	.02	.02	.04	.12	.19	.31	.58	.90			
51	VehEquiv	.01	.07	.03	.00	-.01	.08	.08	-.02	.04	-.21	-.13	-.06	-.06	.01	.01		
52	Q8_PublicTrans	.02	.03	-.11	.02	.02	.04	-.04	.05	-.05	.00	-.04	-.01	-.01	.01	-.01	-.02	
53	Q8_PeerTrans	-.02	-.07	.05	-.06	-.08	-.06	.02	-.09	.08	-.01	.04	.01	.01	-.02	.01	.04	-.81

Although it is possible for people to provide reliable data on their expectations of the conditions under which they would evacuate, it is not likely that they could provide reliable data on the timing of their evacuation. Thus, Figure 11 displays data on the timing of *actual* evacuation decisions for Hurricanes Lili (2002), Katrina (205), Rita (2005) data from the Houston-Galveston Study Area—GSA, and Ike (2008). The figure plots the percentage of evacuees as a function of time before hurricane landfall. In all four events, there was a very low evacuation rate between midnight and 6am, a substantial rise in the evacuation rate between 6am and noon, a decrease in the evacuation rate between noon and 6pm, and a further decrease in the evacuation rate from 6pm-midnight. That is, evacuees prefer to leave during the morning hours so they can reach their destinations during daylight.

However, there are substantial differences in the evacuation rates on different days before hurricane landfall, which were due to differences in the intensity of these storms at the time that authorities needed to make their evacuation decisions. Consequently, local emergency managers and elected officials should recognize that there can be substantial variation in these evacuation rates.

Figure 11. Traffic Loading Functions for Four Hurricanes.



DISCUSSION

In general, the mail surveys completed in the urban areas represented a population with higher income and higher educational attainment in the three counties of the Lower Rio Grande Valley. However, the 190,000 population in the colonias, which have somewhat lower incomes and literacy rates, comprises a significant portion of the entire study area. Thus, the hand-delivered survey in the selected colonias provided an important complement to the urban mail survey since in a hurricane evacuation all the affected residents will share the limited transportation and housing facilities. Interestingly, the up-to-date colonia GIS data visually showed that many colonias have become contiguous with urban areas even if they have not been officially incorporated into them. As the housing demands have risen in recent decades, it appears that the number and area of colonias have also increased and their infrastructure is being improved. The disparities between urban settlements and colonias in their community infrastructure are not as significant as in previous decades so it is not surprising that the patterns of evacuation expectations are relatively similar.

Objectives 1 and 5

<u>Objective 1</u> is to estimate the number of evacuees and evacuating vehicles within the three county study area under various tropical storm/hurricane scenarios—e.g. Tropical Storm and Category 1-5 hurricanes.
<u>Objective 5</u> is to determine the timeframe and how the threatened population will evacuate in response to official evacuation orders and various defined forecast storm conditions such as category of hurricane, and potential flooding.

People's evacuation expectations increased as a function of their proximity to the coast and the hurricane storm category in all three counties. However, the expected rates of evacuation from major hurricanes were quite high in the inland areas of Cameron and Willacy counties and were surprisingly high in all areas of Hidalgo County. The high rates of evacuation shadow indicated in this study appear to be due in part to people's perceptions of the personal impacts on themselves, their families, and their property that are based upon their perceived vulnerability to wind, storm surge, and inland flooding.

Contrary to previous research, a substantial percentage of the respondents (168/220 = 76.4%) correctly identified their risk areas. The self-report accuracy rate is higher than in two previous hurricane evacuation behavioral studies in the Texas coastal counties (35.9% from Arlikatti et al., 2006; 66.4% from Zhang et al., 2004). It is important to note that, in the two previous studies, hurricane risk area GIS maps were provided along with the survey questionnaires, whereas no risk area maps were provided in this study. Consequently, the respondents in this study could judge their risk areas solely by their previously acquired knowledge. Specifically, 90.2% of the urban residents who live in hurricane risk areas accurately identified their homes as being located in a hurricane risk area. Interestingly, 50.0% of the urban residents and 65.9% of the colonias residents who live inland also identified their homes as being in hurricane risk areas. The inland residents' misunderstanding of living in a hurricane risk area was consistent with their high level of expected (shadow) evacuation, especially in response to major hurricanes of categories 3, 4, and 5. This result suggests that VSA emergency managers and policy makers need to make aggressive efforts to provide accurate information about risk area boundaries to local residents and to allocate hurricane evacuation management resources in anticipation of facing overcrowding on evacuation routes.

For all six storm categories, people's expected evacuation decisions were related to official information sources. In particular, the dissemination of hurricane watches and warnings from the National Hurricane Center to local media is the major basis on which people make evacuation decisions. This finding indicates that these information sources could be critical channels for addressing problems of evacuation shadow providing information, as a hurricane approaches, about the need for people in non-evacuation areas to remain in their homes so those in the areas at greatest risk can evacuate safely.

The number of evacuation vehicles per household (1.60 VPH) is very similar to the one (1.62 VPH) reported in a previous Texas coastal survey of hurricane evacuation intentions (Lindell et al., 2001). The consistent intentions of the coastal residents to take more vehicles in evacuation, on the one hand, reflects the need for protecting more of the household's property, and on the other hand, may be explained by the larger household size in this area. VSA emergency managers and elected officials need to rely on the data in Tables 10a-10c to estimate the number of evacuating vehicles in each storm category.

For people who lack their own vehicles, most of them (78.1%) plan to rely on rides with peers (friends, relatives, neighbors, or coworkers). In fact, sharing rides with peers tends to be relatively common during evacuations (Lindell et al., 2011; Wu et al., 2012). Ride sharing will tend to reduce the traffic load on the evacuation routes, although this effect will be slight. Moreover, 14.6% of the respondents lacking their own cars reported expecting to take public transportation. This will be a significant number of households so VSA emergency managers and elected officials need to plan pickup routes throughout the risk areas in order to ensure that these residents are evacuated safely.

The finding that 16.5% of the respondents have household members in need of special medical assistance to evacuate and 55.3% have pets to be evacuated presents a significant challenge to the success of hurricane evacuations. Health care providers have been an indispensable component in evacuation planning and emergency response, especially during catastrophic hurricanes such as Hurricane Katrina. The collocation of local health care facilities and public shelters might be a feasible way to offer medical care to these residents. Mobile first aid vehicles in major transportation nodes can be useful supplements for providing assistance to injured and physically disabled residents in a major evacuation. The American Society for the Prevention of Cruelty to Animals (ASPCA) urges pet owners in hurricane-prone areas to have a hurricane mitigation plan for their pets including making a name tag, obtaining a rescue alert sticker, keeping an emergency kit, and so on (*Emergency Management* News Staff, 2013). Emergency managers can facilitate these caregivers in taking care of pets by coordinating with shelter personnel and local veterinarians in meeting the extra needs of transporting pets in hurricane evacuations.

<u>Objective 2</u> is to determine evacuee destinations, evacuation routes, and places where they plan to seek shelter/refuge.

The survey data on expected evacuation routes and destinations showed: (1) south Texas, in particular San Antonio, is the main evacuation destination along with other Texas cities, such as Houston, Austin, and Laredo; and (2) US-77 and US-281 (two north-south arteries) and US83 (the highway parallel to the U.S.-Mexico boundary) are the principal evacuation routes in VSA. These limited choices for evacuation routes and destinations significantly constrain evacuees' options for escaping from areas affected by hurricane wind, storm surge, and inland flooding and increases the possibility of heavy traffic congestion during evacuation from major hurricanes. The data in Tables 11 and 12 suggest that the westward intrusion of coastal evacuees will substantially interrupt the only two northward US highways (US77 and US281) while evacuees from McAllen and Edinburg leave from the southern end of the Valley for Corpus Christi, San Antonio, Houston, or even more northern cities. Transportation planners and emergency managers will need to carefully coordinate evacuation arrangements at the regional scale in order to avoid traffic jams such as the one that occurred during Hurricane Rita.

A major factor determining evacuees' destinations is the expected availability of places to stay during evacuation. Living temporarily with friends or relatives is the most frequent option (45.3%), staying in a commercial facility (33.3%) is next, and only 6.4% of the respondents expect to choose a public shelter. This pattern is similar to previous hurricane evacuation studies (Lindell et al., 2001; Lindell et al., 2011; Mileti et al., 1992; Wu et al., 2012). Although the demand for beds in public shelters is relatively low in percentage terms, Table 13 indicates that the total number of beds needed in a Category 5 hurricane will be quite large so emergency managers will plan accordingly.

<u>Objective 3</u> is to determine the general level of awareness, hurricane experience, and evacuation experience of the vulnerable population and how this experience may affect the decision to evacuate.

<u>Objective 4</u> is to determine the significant factors influencing the population's decisions to evacuate or stay (e.g., local officials, personal resources, border security checkpoints, social influences, media, job, etc.).

It is notable that about two thirds (62.8%) of the respondents reported having hurricane experience, which might explain their high level of accuracy in identifying whether they lived in a hurricane risk area.

The evacuation inhibitors received only moderate ratings of their likelihood of occurrence and, moreover, had nonsignificant correlations with residents' expectations of evacuating from all storm categories. These results are generally consistent with the result of a previous Texas coastal area survey of hurricane evacuation intentions (Lindell et al., 2001). These results indicate that concerns about property protection, traffic jams, looting risks, evacuation expenses—and especially border security checkpoints—are unlikely to deter people from evacuating.

Storm risks, especially wind damage to property is perceived to be a significant issue by the residents whose houses and communities are in need of the application of wind hazard mitigation measures (e.g., protective covering or envelopes to the entire buildings and shutters installed on windows and doors—Ge et al., 2011). Flooding damage is another common concern for the Valley area, whether coastal or inland. Building elevation, flood insurance, and land use measures are suggested to help protect properties and businesses in the flood prone areas and alleviate the worries of property damage when residents evacuate in response to hurricane warnings. However, the respondents reported modest expectations of disruption to their jobs but strong expectations of disruption to electricity, telephone, and other basic services. However, although expected job disruption was marginally related to evacuation intentions, service disruption expectations were not. Consequently, it does not appear that either form of socioeconomic disruption will significantly affect evacuation decisions.

VSA residents provided high ratings for expected use of evacuation information sources from national to local official channels—NHC hurricane watches and warnings (4.22 out of 5), local TV stations (4.35), national TV networks (3.63), local radio stations (3.69), local officials (3.24), and peers (3.47)—while they expect to rely less on Internet (2.59), local newspaper (2.47), and social media (2.09). This may be due to the relatively low income levels or to limited access to the Internet and social media. Further research is needed to explain the information source disparity of the traditional information source of TV, radio, and peers versus the Internet-based media.

In terms of household emergency preparedness for hurricane evacuation, there was a higher level of adoption of short-term ready-to-use supplies (including flashlight with spare batteries, a battery powered radio with spare batteries, at least 4 gallons of water, at least 4 day supply of food, a first-aid kit, and window protection equipment) than long-term mitigation or response measures (including a household emergency plan, flood insurance, sandbags and sand, and a gas powered electric generator). Possible reasons for the disparities of the items that residents have prepared in their home can be explained as follows. Daily supplies (e.g., food and water) and handy gadgets (e.g., battery powered radios and flashlight) are regularly or can be used for purposes other than (Lindell et al., 2009). In addition, it likely that households lacking disaster experience will tend to adopt fewer pre-impact hazard mitigation (e.g., installing security film, shutters, or plywood to protect windows from wind and debris) or emergency preparedness (e.g., a household emergency plan) actions than those who have experienced at least one hurricane or flooding disaster in the past. Moreover, if a community located in a 100-year floodplain does not require its residents to purchase a flood insurance for their properties through local land use planning or floodplain management, the residents are likely to have inadequate knowledge about the extent of flood damage from a major hurricane or the enormous financial cost of rebuilding their homes after such an event. Therefore, local authorities need to disseminate information about hazard mitigation and emergency preparedness actions so residents can minimize the property losses and fatalities from hurricane wind, storm surge, and inland flooding.

ACKNOWLEDGEMENTS

This research was supported by the U.S. Army Corps of Engineers under Gulf Coast Cooperative Ecosystems Studies Unit Cooperative Agreement Number W912HZ-12-2-0006. We wish to thank Oscar J. Muñoz, Laura Treviño, Myrna Treviño, Jesus Martell, Danyssa Rodriguez, and Samuel Vasquez for their assistance in data collection and Dean Jorge Vanegas for his support of this project.

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APPENDIX A

RIO GRANDE VALLEY

HURRICANE EVACUATION QUESTIONNAIRE

TEXAS A&M UNIVERSITY

HAZARD REDUCTION & RECOVERY CENTER COLONIAS PROGRAM

Office of Management and Budget control number 0710-0001

The public report burden for this information collection is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this data collection, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Executive Services Directorate, Information Management Division, and the Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, D.C. 20503: Attn.: Desk Officer for U.S. Army Corps of Engineers. Respondents should be aware that notwithstanding any other provision of law, an agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Please DO NOT RETURN your completed form to either of these offices.

1. If you have ever been in a community that was advised to evacuate from a hurricane, what did you do (for the most recent hurricane if you have experienced more than one)? (*check only one of the following*)

☐ I stayed; the hurricane hit my community. ☐ I stayed; the hurricane missed my community.
☐ I evacuated; the hurricane hit my community. ☐ I evacuated; the hurricane missed my community.
☐ I have never lived in a community that was advised to evacuate from a hurricane.

2. When deciding whether to evacuate from a future hurricane, to *what extent* would you rely on each of the following for information…	Not at all	Small extent	Moderate extent	Great extent	Very great extent
a. National TV networks (e.g., CNN, Fox News, Weather Channel)	☐	☐	☐	☐	☐
b. Local TV stations	☐	☐	☐	☐	☐
c. Local radio stations	☐	☐	☐	☐	☐
d. Local newspapers	☐	☐	☐	☐	☐
e. The Internet	☐	☐	☐	☐	☐
f. Social media (e.g., Facebook, Twitter)	☐	☐	☐	☐	☐
g. Local officials (e.g., county judge, mayor)	☐	☐	☐	☐	☐
h. Friends, relatives, neighbors, or coworkers	☐	☐	☐	☐	☐
i. National Hurricane Center watches and warnings	☐	☐	☐	☐	☐

3. If local authorities recommend that you evacuate for one of the following conditions, would you do so…	No	Yes
a. Tropical Storm (wind speed less than 74 miles per hour)	☐	☐
b. Category One Hurricane (74-95 miles per hour)	☐	☐
c. Category Two Hurricane (96-110 miles per hour)	☐	☐
d. Category Three Hurricane (111-129 miles per hour)	☐	☐
e. Category Four Hurricane (130-156 miles per hour)	☐	☐
f. Category Five Hurricane (more than 156 miles per hour)	☐	☐

(*If you answered "no" to* ***all*** *of the conditions above, skip to Question 12*)

4. If local authorities recommend evacuation for your community, to *what extent* would the following considerations affect your decision whether or not to evacuate?	Not at all	Small extent	Moderate extent	Great extent	Very great extent
a. The possibility of being involved in a major traffic accident	☐	☐	☐	☐	☐
b. The possibility of being stuck for many hours in a major traffic jam	☐	☐	☐	☐	☐
c. The need to protect my home from storm impact	☐	☐	☐	☐	☐
d. Loss of income while away from work	☐	☐	☐	☐	☐
e. Out of pocket expenses for gas, food, and lodging while away from home	☐	☐	☐	☐	☐
f. The possibility of looting in evacuated areas	☐	☐	☐	☐	☐
g. Concerns about border security checkpoints	☐	☐	☐	☐	☐

5. Does your household have…	No	Yes
a. household members who need special medical assistance to evacuate?	☐	☐
b. pets that will be evacuated with other members?	☐	☐

6. How many registered motor vehicles does your household have?___________ **vehicles**

7. How many of the following would your household take with you in an evacuation?

a. cars or trucks ___________
b. boat trailers or other trailers ____________
c. motor homes or recreational vehicles (RVs) ____________

8. If you don't have your own car or truck, what would you use to evacuate? (*check only one of the following*)

☐ Use public transportation ☐ Get a ride with a friend, relative, neighbor, or coworker
☐ Other (please specify) ____

9. What city would be your final destination if you evacuate? ________________________________

10. What major highways would you take to evacuate to this destination?
____
____

11. Where would you stay while away from home during a hurricane evacuation? (*check only one of the following*)	
☐ With friends or relatives	☐ In a hotel or a motel
☐ In a public evacuation shelter	☐ Don't know
☐ Other (please specify) ______________________________	

12. How *likely* do you think it is that there will be a hurricane in the next five years that will cause…	Not at all likely	Small likely	Moderate likely	Great likely	Almost certain
a. major damage to property in your community?	☐	☐	☐	☐	☐
b. deaths and injuries to people in your community?	☐	☐	☐	☐	☐
c. major damage to your home from storm wind?	☐	☐	☐	☐	☐
d. major damage to your home from (saltwater) storm surge?	☐	☐	☐	☐	☐
e. major damage to your home from (freshwater) flooding?	☐	☐	☐	☐	☐
f. injury or death to yourself or members of your household?	☐	☐	☐	☐	☐
g. disruption of your job that prevents you from working?	☐	☐	☐	☐	☐
h. disruption of electrical, telephone and other basic services?	☐	☐	☐	☐	☐

13. Do you have any of the following in the place where you live?	No	Yes
a. A battery powered radio with spare batteries	☐	☐
b. At least 4 gallons of water stored in plastic containers	☐	☐
c. At least a 4 day supply of dehydrated or canned food for yourself and your family	☐	☐
d. A complete first-aid kit	☐	☐
e. Flashlight and spare batteries	☐	☐
f. Security film, shutters, or plywood to protect your windows from wind and debris	☐	☐
g. Sandbags and sand to protect your house from flooding	☐	☐
h. A gas powered electric generator	☐	☐
i. A household emergency plan	☐	☐
j. Flood insurance	☐	☐
14. Is the place where you live…	No	Yes
a. elevated so water passes under it?	☐	☐
b. dry floodproofed so water cannot get in?	☐	☐
c. wet floodproofed so water can get in but equipment such as the furnace, air conditioner, washer, and dryer is above expected flood level or protected by a floodwall?	☐	☐
15. Is the place where you live located in a…	No	Yes
a. hurricane risk area?	☐	☐
b. Federal Emergency Management Agency (FEMA) flood zone?	☐	☐

16. How old are you? ___________ **years**	
17. What is your sex?	
☐ **Male**	☐ **Female**
18. Which of these best describes your ethnic background?	
☐ **Non-Hispanic**	☐ **Origin Hispanic Origin**
19. Which of the following best describes your race?	
☐ **White**	☐ **Black**
☐ **Asian or Pacific Islander**	☐ **American Indian or Alaskan Native**
20. What is your marital status?	
☐ **Married**	☐ **Single**
☐ **Divorced**	☐ **Widowed**

Please turn the page to answer the questions on the back.

21. What is your highest level of education?

☐ **Less than high school** ☐ **High school graduate** ☐ **Some college/vocational school**
☐ **College graduate** ☐ **Graduate school**

22. What is your *yearly* household income?

☐ **Less than $15,000** ☐ **$15,000–30,000** ☐ **$30,000–45,000**
☐ **$45,000–60,000** ☐ **More than $60,000**

23. How many people in your household are:

___________ **Under 18 years** ___________ **18-65 years** ___________ **Over 65 years**

24. Do you rent or own the home where you are currently living?

☐ **Rent** ☐ **Own**

25. Which of the following best describes the type of structure in which you live?

☐ **Detached single family home** ☐ **Multi-family, one or two stories**
☐ **Multi-family, three or more stories** ☐ **Mobile or manufactured home**
☐ **Other** (please specify) ______________________________

26. Compared to other buildings in your neighborhood, how vulnerable do you think your home is to damage from......	Much less than average	Less than average	In average	More than average	Much more than average
a. hurricane wind	☐	☐	☐	☐	☐
b. salt water surge inundation	☐	☐	☐	☐	☐
c. inland (freshwater) flooding	☐	☐	☐	☐	☐

27. Do you have any additional comments about hurricane evacuation?

____

Please return the questionnaire in the envelope provided. ***Thank You.***