The Status and Trends of Population Social Vulnerabilities along the Texas Coast with special attention to the Coastal Management Zone and Hurricane Ike: The Coastal Planning Atlas and Social Vulnerability Mapping Tools

by

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I. Introduction

Disasters like hurricane Ike, as well as storms that have struck Texas in the past, such as Allison, Katrina, and Rita, are generally referred to as "natural" disasters. Rather than being wholly "natural," however, these disasters result from the interaction among biophysical systems, human systems, and their built environment. Indeed, the emerging scientific consensus is that the damage incurred—in both human and financial terms—is largely due to human action or, more often, inaction (Mileti 1999). As we have shown in earlier reports from the Status and Trends to Coastal Hazards Project, many of Texas's coastal communities, as with much of the United States, continue to develop and expand into high hazard wind and surge areas along the coast, contributing to increased hazard exposure (Peacock et al. 2010). This expansion often results in the destruction of environmental resources such as wetlands and barrier islands that can reduce losses. In other words, many of our coastal communities in Texas are becoming ever more *vulnerable* to "natural" hazards while simultaneously becoming less disaster *resilient*. This report takes the assessment of the growth and expansion of Texas's population into high risk coastal areas a step further by considering the social and economic characteristics of this expanding population.

When disaster strikes, its impact is not merely a function of its characteristics such as its magnitude and the location where it strikes. For example, like most communities Galveston is composed of many unique neighborhoods and places. Some of its neighborhoods are composed of beautiful homes whose occupants' lives are characterized in terms of relative wealth, leisure, and privilege while other neighborhoods have run down homes and are plagued by poverty, crime, and unemployment. Development patterns that are all too often characterized by sprawl, concentrated poverty and segregation shape our communities' urban environments in ways that separate and often isolate vulnerable populations in a manner such that poor and rich, Black, White and Hispanic, owners and renters, primary residents and vacationers are separated from one another in clusters and pockets across the Island. In a disaster event like Ike, the socio-economic geography of our communities can interacts with the physical geography to expose vulnerable populations to greater impact. Lower-income populations often live in low-lying areas and in lower-quality homes that are at greater risk. Furthermore, vulnerable populations are less likely to have access to both information and resources that would allow them to anticipate and respond to a real or perceived threat, yet they are more often than not the groups who most need to heed warnings to evacuate or seek shelter.

Community vulnerability, in its broadest sense, describes the susceptibility of a community or, importantly, its constituent parts to the harmful impacts of disasters. Variation in existing vulnerabilities influences the exposure of households, businesses, and communities to effects of natural hazards as well as the capacity and resources available to respond to and recover from disasters. In other words, storms like Ike were and are not "equal impact" events—they affect different groups, sub-populations and neighborhoods in different ways. While some can easily anticipate and respond to hazard threats by putting up hurricane shutters or evacuating to relatives and friends further inland, others find it more difficult if not impossible. And then, in the aftermath of a devastating disaster, recovery can be highly uneven, with some parts of a community recovering relatively more quickly as insurance companies respond more readily, expediting their abilities hire contractors or builders to have their homes repaired or rebuilt, while others neighborhoods lag behind. The uneven nature of recovery can jeopardize the overall vitality and resiliency of a community and bring into question its future.

This report provide an expanded view of community vulnerability, focusing on how social and economic factors influence the ability of coastal communities and their populations (individuals and households) to anticipate, respond, resist, and recover from disasters. It will first present a discussion of the literature on social vulnerability and discuss previous findings showing how social vulnerabilty can shape disaster response. We then present the approach for measuring, assessing and mapping social vulnerability along the Texas coast using the Texas Coastal Community Planning Atlas[1]. Employing data from the Atlas, we also discuss the status and trends in social vulnerability from 1980 through 2000 focusing on areas within the coastal management zone (CMZ). Finally, using data from Galveston, we will examine patterns of social vulnerability prior to Ike and show how these pre-existing patterns are related to differential response to warning, impact, access to recovery resources, and the initial stages of recovery. We conclude that undertaking a spatial analysis of social vulnerability should be a critical element in emergency and hazard management, hazard mitigation and disaster recovery planning. Our findings suggest that social vulnerability analysis can help communities reduce losses, enhance response and recovery and thereby strengthen community resilience.

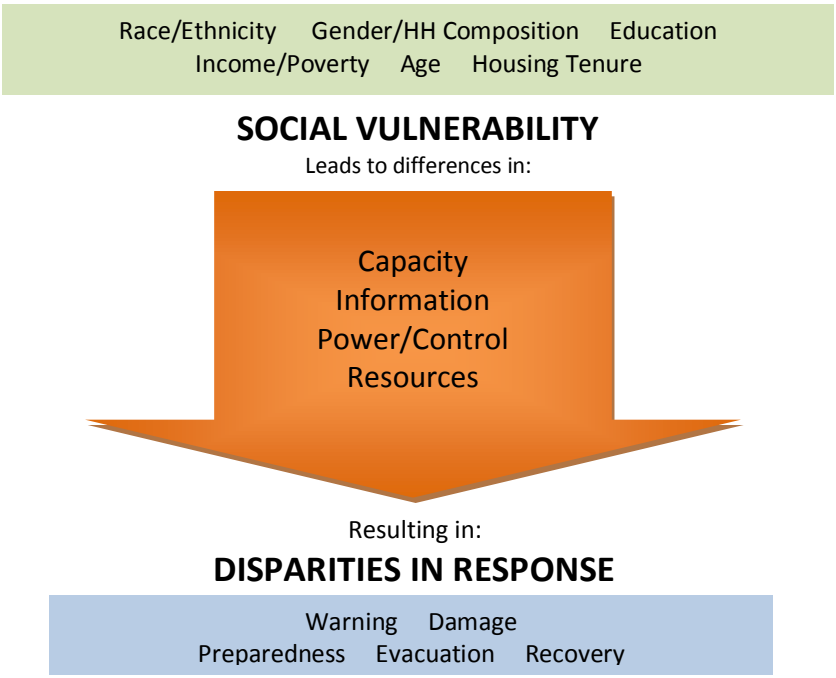
II. Social vulnerability (SV)

Vulnerability has become a central yet evolving concept in hazard analysis and research (White, Kates and Burton 2001:86; NRC 2006; Naudé, Santos-Paulino and McGillivary 2009). When considering natural hazards, *vulnerability* generally refers to susceptibility or potential for experiencing the harmful impacts of a hazard event (Cutter 1996; Mitchell 1989). The foundation of vulnerability analysis, a hazards assessment, generally focuses on a community's exposure to hazard agents such as

[1] <coastalatlas.tamu.edu> or <coastalatlas.tamug.edu>.

floods, surge, wave action, or winds (Deyle et al. 1998; NRC 2006:72-3). Such assessments identify the potential exposure of populations, businesses, and the built environment (housing, infrastructure, critical facilities, and so on). Also important are the physical characteristics of the built environment such as wind design features of buildings, the height of structures relative to potential floods, as well as natural and engineered environmental features such as wetlands, dams, levees or sea walls, because these can modify vulnerabilities and concomitant risk. As disaster and hazard researchers critically examined the nature and distribution of disaster impacts and the factors shaping the variability in exposure and access to technology that can mitigate impacts (i.e., shutters, impact resistant glazing etc.), it became clear that more than just more than just hazard exposure and the built and natural environment were also shaping vulnerability. A new perspective began to emerge suggesting that social structures and processes also shape vulnerability; hence, the term *social vulnerability (SV)*.[2]

Figure 1. Conceptual model of how vulnerabilities lead to disparities in disaster response.



Social vulnerability is defined by Blaikie, Cannon, Davis, and Wisner (1994:9) as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of a natural hazard." A SV perspective focuses attention on the characteristics and diversity of populations in terms of broader social, cultural, and economic factors that shape abilities to anticipate future events, respond to warnings, and to cope with and recover from disaster impacts. While the SV literature continues to grow, it has examined a variety of

[2] Similar lines of thought were evident in what has been termed the Environmental Justice research (e.g., Bullard1990; Bryant and Mohai 1992; Pastor, Bullard, Boyce, Fothergill, Morello-Frosch and Wright 2006).

hazard and disaster contexts identifying dimensions of social vulnerability related to race/ethnicity (Bolin 1986; Bolin and Bolton 1986; Perry and Mushkatel 1986; Peacock et al. 1997; Bolin and Stanford 1998; Fothergill, Maestas, and Darlington 1999; Lindell and Perry 2004; Zhang and Peacock 2010), income and poverty (Peacock et al. 1997; Dash et al. 1997; Fothergill and Peek 2004), gender (Enarson and Morrow 1997; Enarson and Morrow 1998; Fothergill 1999) as well as a host of other factors such as age, education, religion, social isolation, housing tenure, etc. Very often, these factors are present in combinations (both poor and Black, for example), which can exacerbate vulnerability (Morrow 1999). Conceptually, this perspective is presented in Figure 1, where preexisting social vulnerability factors shape access to information and resources and hence shape disaster response.

Policies and practices related to disaster response often assume that all residents of an area have the same information as well as the same resources and ability to act upon that information. Further, they assume that all residents will react in the same way. Social vulnerability factors, however, can shape and influence access to and knowledge of resources (physical, financial, and social), control of these resources, as well as perceived or real power within the larger community or society. They may also influence the capacity of the individual or household to act (see Figure 1). For example, some research suggests that African-Americans often rely on informal social networks rather than media or government to obtain information about threats or hazards (Perry and Lindell 1991; Morrow 1997). Even if a resident has the same information, he or she may not have the capacity (a car, for example) to evacuate in a timely manner. Renters are typically more mobile or transient and may not have local family connections to facilitate evacuation or sheltering, while owners are more likely to have such resources, but also are more place-bound, in that they often express concerns about their homes and contents. As a result of these differences, responses to disasters may be quite disparate.

The following offers a brief review of the research literature illustrating how dimensions of SV are related to household and individual response to critical disaster stages: a) preparedness, b) warning, c) evacuation, d) casualties and damage, e) reconstruction and recovery and f) mitigation.[3]

a. Preparedness: Actions undertaken prior to an event, such as disaster planning, having supplies on hand, securing the home and contents and installing window protection that can reduce or eliminate potential impacts are all examples of disaster preparedness. Interestingly, despite the general finding that minority status and lower-income is associated with higher risk perceptions for natural and technological hazards (Flynn, Slovic, and Mertz 1994; Vaughn and Nordenstam 1991; Vaugh and Seifert 1992; Turner, Nigg and Paz 1986; Lindell and Prater 2000; Peacock, Brody, and Highfield 2005), on the whole minorities and low income households display lower levels of preparedness. With respect to earthquake preparation, a number of researchers found preparation less common among

[3] The this typology and the following discussion draws heavily from two excellent reviews of the disaster and hazards literature related to race/ethnicity (Fothergill, Maestas, and Darlington 1999) and poverty (Fothergill and Peek 2004).

minorities than whites (Turner et al. 1986, Farley 1998, Edwards 1993, Mileti and Darlington 1997). Similar findings are reported for Black households with respect to hurricane preparation supplies (Norris et al. 1999) and Morrow and Enarson (1996) noted that prior to Hurricane Andrew poor women in public housing heard warnings and wanted to prepare, but simply lacked the economic resources for supplies. Even among homeowners Florida, both low-income and Black households were less likely to have code-compliant hurricane shutters to protect their homes from hurricanes. These findings are not completely consistent across hazards or regions, where, for example, some researchers found no racial/ethnic variations with respect to flood preparation (Lindell et al. 1980, Ives and Rurseth 1983) and with hurricane preparedness in Miami (Gladwin and Peacock 1997). On the whole however, the literature suggests somewhat higher vulnerabilities for lower-income and minority households with respect to disaster preparation.

b. Warning: Disaster warning processes begin with receiving and then believing a warning, where source credibility and conformation can be critical, and hopefully ends with undertaking protective action such as evacuating (Lindell and Perry 2004). Although findings are not always consistent, the general pattern suggests that race/ethnicity, income and other SV factors can be important. For example, researchers found that among Hispanics in general (Mexican-Americans in particular) and Blacks, social networks and relatives are more important for relaying warning and disaster information (Perry and Mushkatel 1986; Phillips and Ephraim 1992; Perry and Nelson 1991; Blanchard-Boehm; Morrow 1997). Similarly, research suggests that Anglos are more likely to report the authorities and the media as most credible when compared to minorities that tend to pick social networks as most credible (Perry and Lindell 1991, Lindell and Perry 1992). Interestingly, Perry and Lindell (1991) found that Whites were somewhat less likely to require message confirmation, which is consistent with conclusions by Perry and Mushkatel (1986) that Whites more strongly believe warnings than do either Blacks or Mexican-Americans. These findings suggest that minorities may experience potential delays in receiving and confirming warning messages since they display greater dependence on informal social and familial networks.

c. Evacuation: Research on evacuation is somewhat equivocal, but on the whole it suggests that minorities, lower-income groups, and aged are less likely to respond to warnings. Early research found that minorities and lower-income populations fail to comply with warnings (Moore 1958; Sims & Bauman 1972). Lindell, Perry and Greene (1980) examining flooding response found that Mexican Americans were less likely to evacuate and Drabek and Boggs (1986) found that Mexican-American households were more dependent on extended family ties to facilitate evacuation. On the other hand, Perry and Lindell (1991), examining flooding and hazards material spills, report limited to non-significant ethnic variations in evacuation. Gladwin and Peacock (1997) however, found that low-income and black households were less likely to evacuate prior to Hurricane Andrew. They speculate that this is due in part to a lack of resources, particularly private vehicles, ineffective public transportation options, and few refuge options outside evacuation zones. Morrow and Enarson (1996) and Morrow (1997) found that prior to Hurricane Andrew poor

women and others in public housing lacked transportation, forcing many to walk or hitchhike in order to evacuate. Similarly, Enarson (1999) found that the homeless, unemployed and lower-income women were less able to evacuate in response to Red River Valley flood warnings. These findings are consistent with the failures of many poorer and minority households to evacuate New Orleans in response to Katrina. Lindell and Perry (2004:90) also suggest that income and education might have consequences for evacuation in response to warning, "due to restricted material resources, knowledge, and skill."

d. Casualties and Damage: Research examining variations in *casualties and damage* suggests that minorities and low-income groups are much more likely to be disproportionately impacted and hence more vulnerable to flooding. In one of the earliest studies examining casualties due Hurricane Audrey, Bates et al., (1963) found significantly higher death rates among Blacks (322 per 1000) compared to Whites (38 per 1000). Bolin and Bolton (1986) reported that following the Paris tornado, Black respondents were significantly more likely to report friends being injured (19.6% to 9.9%) and killed (31.1% vs. 17.5%) when compared to Whites. Rossi et al. (1983) examined injuries due to various disasters from 1970 through 1980, and found that lower income areas experienced significantly higher injuries, particularly when examining floods and earthquakes. Aguirre (1988) similarly found that the poor had higher injury and deaths following a Texas tornado in 1987. More recently, Zahran and his colleagues (2008) found that counties with higher concentrations of socially vulnerable populations, defined by race, poverty and income, had higher flood casualty rates from 1997 – 2001 in Texas.

The research on damage and losses due to disasters suggests that minorities and lower-income households suffer disproportionately. In large measure this appears to be due to trickle down housing processes in the United States whereby the poor and minorities are often allocated to older and poorer quality housing, often segregated into less desirable and potentially more risky neighborhoods and areas (Foley 1980; Bolin 1986; Bolin and Bolton 1986; Logan and Molotch 1987; Greene 1992; Massey and Denton 1993; Phillips 1993; Phillips and Ephraim 1992; Peacock and Girard 1997; Charles 2003; Peacock, Dash, and Zhang 2006; Van Zandt 2007). Bolin and Bolton (1986), for example, found that minorities and low income households suffered disproportionate losses from both tornados and earthquakes (see also, Bolin 1986, Bolin and Stanford 1991 and 1998). Fothergill and Peek (2004), citing data from the U.S. Department of Commerce, noted that nearly 40% of all tornado fatalities occur among mobile home residents, which are more likely to be occupied by low-income households. Peacock and Girard (1997) found that, once housing type is controlled, income variations become non-significant, and yet both black and Hispanic household suffered higher levels of damage when compared to Anglos in Hurricane Andrew (see also Zhang and Peacock 2010). The findings with respect to flooding are not as consistent. Indeed, Brody and his colleagues (2007), examining damage losses due to flooding in Texas coastal counties from 1997-2001 found that a county's median household income was not related to total property losses.

e. Reconstruction and Recovery: The literature suggests that minorities, low-income households, and even female- headed households can be at a disadvantage in part because of low language skills and education when it comes to qualifying for and negotiating the process of obtaining public financial resources such as SBA loans or minimum housing assistance (Phillips 1993; Bolin 1985; Bolin and Stanford 1990; Morrow 1997; Morrow and Enarson 1997). Furthermore, racial/ethnic groups are often excluded from community post-disaster planning and recovery activities because they have less economic power and political representation (Bolin and Bolton 1983; Quarantelli 1985; Tierney 1989; Phillips 1993; Morrow 1997; Morrow and Peacock 1997; Prater and Lindell 2000). Research further suggest that poorer households and neighborhoods often fall far short of receiving necessary aid to jump start the recovery process (Rubin 1985; Bolin and Stanford 1991; Phillips 1993; Berke et al. 1993; Bolin and Stanford 1991; Dash et al. 1997), particularly when it comes to qualifying for SBA loans and private insurance settlements necessary for housing recovery.

Research has shown that low-income and minority homeowners are much more likely to fail to qualify for government-backed SBA loans (Bolin 1982; Drabek and Key 1984; Quarantelli 1982; Bolin and Bolton 1986; Bolin 1986; Bolin 1993b; Bolin and Stanford 1998a and b), although more recent research suggests that ethnic/racial variations may no longer be significant (Galindo 2007). While early research found that low-income and minority households were more likely to be without insurance (Moore et al. 1963 and 1964; Cochrane 1975; Drabek and Key 1984), later research suggests more parity in holding insurance policies, but that poor and minority households were more likely to report settlements failing to meet repair and reconstruction costs (Bolin 1982; Bolin and Bolton 1986). Peacock and Girard (1997) found a similar pattern in Miami-Dade County following Hurricane Andrew where both Black and Hispanic households were more likely to report insufficient insurance settlements for repairs and reconstruction. Further analysis suggested that this was a function of the insurance company. Specifically, large national insurance companies that were more likely to provide adequate settlements had systematically failed to underwrite insurance in minority, and particularly Black, neighborhoods. The literature also suggests that rental housing is slower to recover, which makes it more difficult for minority and low-income households to find post-disaster housing and return to their pre-disaster communities, often extending the recovery process (Quarantelli 1982; Comerio 1998; Comerio et al. 1994; Bolin 1986, 1993b; Bolin and Stanford 1998a and 1998b; Morrow and Peacock 1997). Indeed, in one of the few longitudinal studies of housing recovery following a major natural disaster, Hurricane Andrew in Miami-Dade county, Zhang and Peacock (2010) found that housing in predominantly minority (Black and Hispanic) neighborhoods as well as rental housing, was much slower to recover.

f. Hazard Mitigation: Hazard mitigation generally refers to actions undertaken prior to a disaster that act as protection against disaster impacts passively (Lindell Prater and Perry 2010). In other words, these are actions that once taken help reduce impact, lessen the consequences of impacts, but do not necessarily need to

be undertaken at the time of an event. Past literature referred to mitigation actions as hazard adjustments. These adjustments range, at the community level, from major structural adjustments such as building dams and levees, to land use regulations, building codes, and education programs. At the individual or household level these adjustments could be installing hurricane shutters or impact resistant windows in hurricane risk areas, elevating homes hurricane surge or inland flooding risk areas, to strapping water-heaters and bookshelves to the walls in earthquake areas.

The literature on mitigation and hazard adjustments at the household level is often associated with a number of SV factors. For example, researchers have found that income is positively associated with the ability to undertake a variety of adjustments (Edwards 1993; Russell et al. 1995; Lindell and Prater 2000). Peacock (2003), found that high income households were much more likely to have hurricane shutters installed on their homes and were also more likely to have more complete protection for their home (i.e., their home's envelope) when considering windows, garage doors, sliding glass doors, etc. However, Lindell and Perry (2000) have noted, the results have been somewhat inconsistent across all types of adjustments. Peacock (2003) suggests, these inconsistencies could be a function of the variability in the types of adjustments considered. Often times researchers have constructed hazard adjustment indices that include relatively large proportions of low investment items such as flashlights, batteries or simply attending meetings. When considering such low investment items it, perhaps is not surprising that income has little in the way of consequences. However, when considering adjustments that will demand significant capital outlays, like shutters, new roofs, elevating home etc. higher income households will have more disposable income and potential accesses to credit to make these rather substantial investments.

Researchers have also found that race and ethnicity have consequences for hazard mitigation adjustments (Edwards 1993; Mileti and Darlington 1997). Indeed, Peacock (2003) in his research on homeowners in Florida also found that Black households, when compared to Anglo households and after controlling for a host of other factors, were less likely to have quality shutter systems and envelope coverage. The author suggested that the reasons for these differentials were due, in part, to racial and ethnic variations to credit and capital. For example, research on home ownership and access to loans suggests significant ethnic variations, with minorities particularly Blacks having significantly lower access to these scarce resources Squires and Velez 1987; Horton 1992; Alba and Logan 1992; Massey and Denton 1993; Oliver and Shapiro 1997) and when they do, payments and interest rates are often higher. The implication is that minorities, particularly Black households will have reduced access to the capital resources necessary to make home improvements and retrofits. It is also interesting to note that Peguero (2006) has found significant ethnic differentials, particularly with respect to Latino households, in sources of information related to mitigation. Specifically he found that Latino homeowners in Florida tend to rely most on friends and family, and less on governmental or official sources.

On the whole, then, the literature suggests that SV factors can be important determinants of vulnerability and hence should be considered when undertaking disaster planning related to warning, response, impact, recovery and mitigation. Further, and importantly, socially vulnerable populations are not evenly distributed throughout communities. Instead, they tend to be clustered into particular locations or neighborhoods. On one hand, such clustering exacerbates the impact of disasters; on the other hand, it may also make it possible for public officials to address such disparate outcomes through spatially-targeted efforts both prior to and after a disaster. In the next section, we explore the use of a spatial decision-making tool to both identify and address the needs of socially vulnerable populations.

III. Social Vulnerability Mapping: The Coastal Planning Atlas Approach

While the above discussions on social vulnerability clearly suggest that a host of factors from age, to income and even minority status can indeed be important when seeking to understand and predict the variability in the abilities of populations to anticipate, respond and recover from disasters, the inclusion of these factors into community planning and vulnerability analysis has been slow to develop. Indeed, it was not until nearly the turn of the century that researchers began to call for the systematic application of social vulnerability perspectives at the community level to develop social vulnerability mapping (Morrow 1999). The basic logic was to identify concentrations of populations with particular SV characteristics in order to identify areas within a community that will perhaps require special attention, planning efforts, and mobilization to respond to and recover from disasters and hazards. The following begins by discussing the areal units of analysis for our mapping strategy and then discussed the data utilized and the construction of the SV measures.

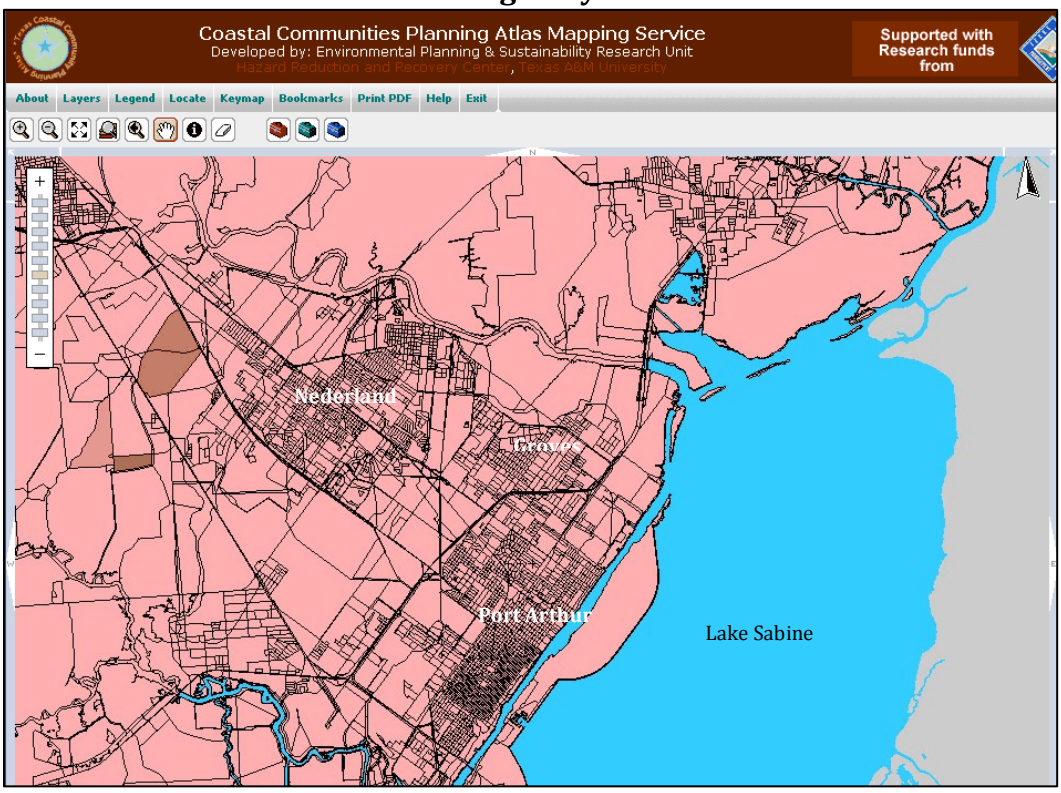
Units of Analysis

Susan Cutter and her colleagues have been one of the few research groups to systematically undertake social vulnerability mapping utilizing a variety approaches to identify spatial units ranging from census tracts to counties and states, seeking to extend and apply research that generally focuses on individuals or household level (Cutter, Mitchell, and Scott 2000; Cutter 2001; Boruff, Emrich and Cutter 2005). Cutter, Boruff, and Shirley (2003), for example, undertook an extensive analysis of the vulnerability literature drawing together a set of 85 indicators of social vulnerability ranging from median age through social security receipts per capita for over 3,000 counties in the United States in 1990. While their approach is quite comprehensive and national in scale, the approach taken here is more conducive for community-based planning.

Our goal in creating social vulnerability mapping tools in the Texas Coastal Planning Atlas (CPA) was to use readily available data from secondary sources such as the U.S. Census, to allow for broad application of the technique to all communities and yet provide for sufficiently fine resolution that planners and emergency managers might easily identify and potentially target more or less homogeneous pockets of socially vulnerable populations. The logical census areal units (and data) that might be employed to map parts of a community were census blocks, block-groups, or

tracts. Tracts are the largest areal unit that might be possibly employed. They are designated by the census to have relatively stable boundary over several census decades. Their boundaries often follow more or less recognizable physical features of a community and generally contain between 1000 to 8000 individuals. Tracts have a major advantage of offering rich social and economic data to measure dimensions of SV. However, relatively speaking they also tend to be quite large, often times encompassing multiple neighborhoods and even smaller communities. Because they are so large they can be quite heterogeneous and fail to capture neighborhoods that are natural areas to organize and work with for planners and emergence managers. Census blocks, on the other hand are quite small and homogeneous, and generally capture quite refined areas much like blocks within communities. Unfortunately since they are so small, and individuals can be more easily identified, the US Census provides only minimum data for blocks and these data are far too limited to capture many SV dimensions. Block-groups offered a viable compromise in that they fall between tracts and blocks, offer relatively refined data relevant for measuring various dimensions of SV, and yet are also sufficiently small in spatial scale that they often matched more or less homogeneous neighborhoods.

Figure 2. Census Blocks in Port Arthur, Groves, Nederland and Bridge City Texas



These distinctions can be readily seen in the maps provide in Figures 2, 3 and 4 which are of the Texas side of Lake Sabine with the city of Port Arthur on the west

side of the lake, Groves Texas just to the north of Port Arthur, with Nederland, Port Neches, and Central Gardens to the north west of Port Arthur. Figure 2 displays a map of census blocks, which are so refined that they often time identify actual individual blocks within these cities. They would be ideal to use for SV mapping because they are so small that one could get a very clear picture of the individuals residing in these blocks. However, it is precisely because they may contain so few individuals and households that the US Census does not release much in the way of detail data on the individuals and households in these units. For example, data on the numbers of individuals, household and basic racial information is often the best that is obtainable, although even here, in very small blocks even racial information might be withheld. The bottom line is that the data available for these census units is far too limited for use when seeking to identify socially vulnerable individuals or households.

Figure 3. Census Tracts in Port Arthur, Groves, Nederland and Bridge City Texas

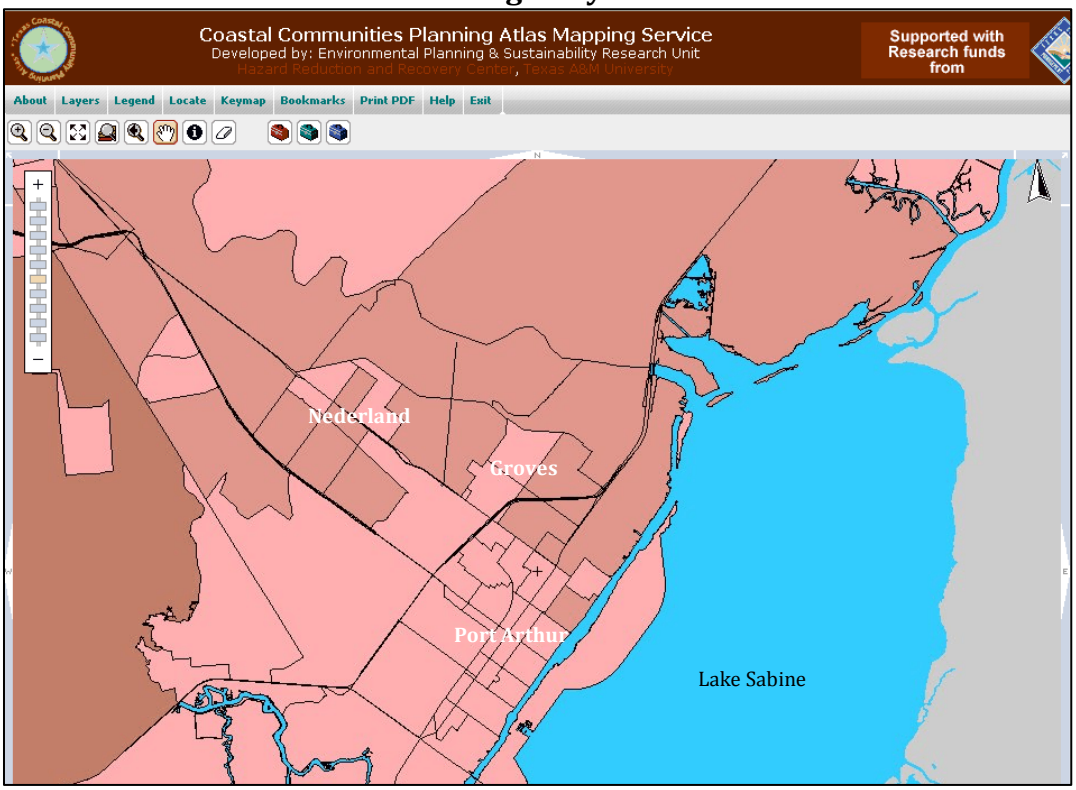


Figure 3, above, displays a map of census tracts for the same area. While these census areal units would provide very rich data upon which to base the SV measures, these spatial boundaries are rather large. Port Arthur is reduced to a relatively small number of census tracts, but even more dramatic are the consequences for Nederlands and Groves which are reduced to very few unrecognizable geometries that encompass multiple neighborhoods. These relatively large areas, besides not capturing recognizable neighborhoods are often quite heterogeneous in terms of

population and housing characteristics. As a result these units can make it very difficult for planners and emergency managers to utilize the information to shape policies and actions to better respond to disaster threats.

Figure 4, on the other hand, displays census block group boundaries, again for the same area. These represent our compromise spatial unit upon which to base our SV maps. As we will shortly see the census provides rather refined and relatively rich data for these spatial areas that will allow for good definition of SV characteristics. Equally important, these spatial boundaries while not perfect, often demarcate neighborhood areas or parts of neighborhoods that are easily recognizable to local planners, emergence managers, and citizens themselves. This can therefore facilitate effective development of policies and the targeting of programs to address hazards and disaster response. The extent to which they reflect actual neighborhood boundaries can greatly enhance the ability to work with local neighborhood organizations, businesses, churches, neighborhood associations, and other civic organizations to organize the neighborhood.

Figure 4. Census Block Groups in Port Arthur, Groves, Nederland and Bridge City Texas

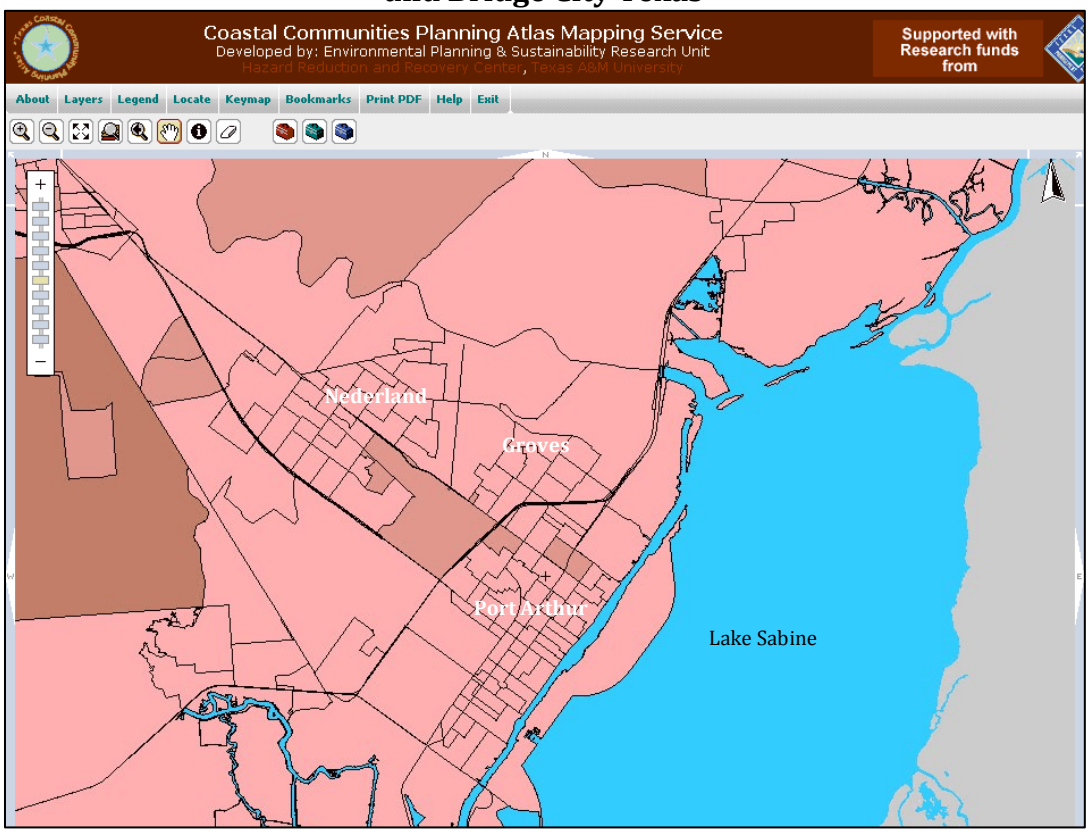
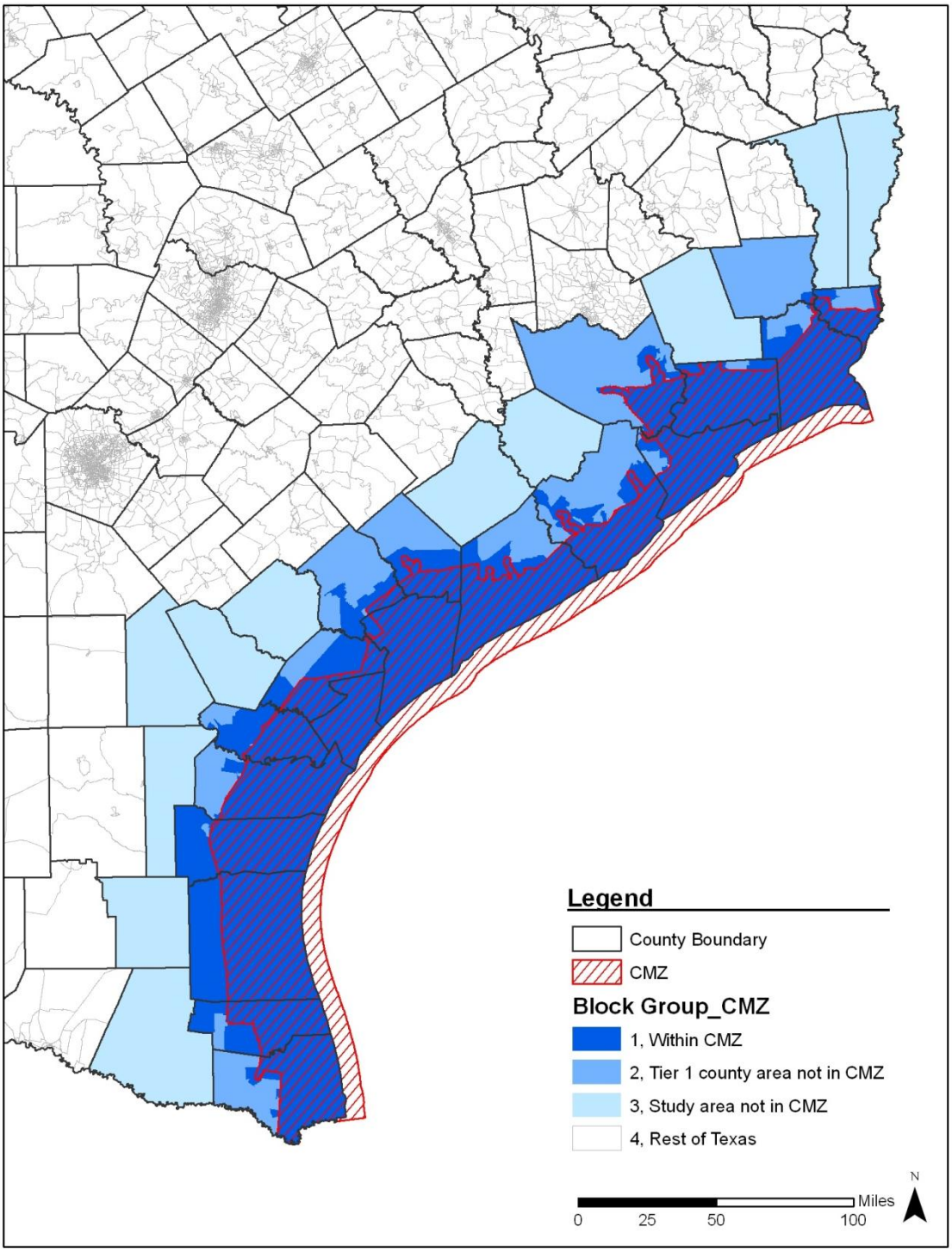


Figure 5. Coastal Atlas Counties, CMZ boundary and Block Groups



The coastal atlas has data on the 3993 census block groups located in the first two layers of counties of the Texas coast. At times we will utilize and present all of these data, however, for much of this report we will focus on areas within the coastal management zone. Specifically, we have identified 1,322 census block groups located either wholly (100%) or partly (minimum of 10%) within the Texas's CMZ.

Figure 5 displays a map of the first two tiers of coastal counties that are part of the Coastal Planning Atlas. These counties are displayed in blue (dark, medium, and light). The Coastal Management Zone Boundary is marked in red on this map and all block groups that are included in our analysis as CMZ block groups are indicated in dark blue. As is apparent from the map some of these block groups extend beyond the CMZ boundary. More often than not, these are rural block groups that are sparsely populated and hence quite large. Unfortunately, it is often the case that the population concentrations for many of these block groups are actually within that part of block group that is within the CMZ. To better insure that population concentrations that are actually within the CMZ are included in our analysis, if more than 10% of a block group's physical area fell within the CMZ, the block group was considered part of the CMZ.

Social Vulnerability Data and Indices

The selection of SV indictors was guided by the literature on social vulnerability, some of which was discussed above, and, of course, was contingent on the data available from the US Census and attached to block groups that most closely captured attributes discussed in the literature. Table 1 displays the 17 base or 1st order indicators utilized to identify socially vulnerable populations. The indicators include a range of factors related to household structure (single parent households with children), age (children at or below 5, individuals ≥65, and individuals ≥65 living in poverty), transportation dependence (reliance on public transportation or households not having a car), housing characteristics (occupancy, mobile homes, group quarters), minority status (non-white population), poverty (population below the poverty level), educational status (individuals 25 or older without a high school diploma or equivalent), employment status (unemployment) and English language competency (individuals ≥5 not speaking English well or at all). Each of these indicators was transformed into a proportion[4] (ranging from 0 to 1) by dividing it by an appropriate base to facilitate their comparability across block-groups. In each case, the closer to one (1) a block group's proportion, the higher the concentration of vulnerability.[5] These 1st order SV indicators capture important dimensions of social vulnerability, which is, by its nature multi-dimensional (Morrow 1999). An additional advantage of having these 17 basic or 1st order SV measures available to process and map at the local level is that planners can more easily identify and perhaps focus on particular types of policies and programs to address specific dimensions of vulnerabilities given particular hazard risks. Examples might be programs targeting non-English speaking populations or elderly populations to enhance their compliance with evacuation orders. Furthermore, there are a host of many different types of funding and assistance programs at the Federal, State and local level that might be available to address different types of community needs,

[4] These proportions can, of course, be converted to percentages by simply multiplying them by 100.
[5] The exception to this rule might be occupied housing units. In this case the higher the proportion occupied housing units, the few the housing units that might be available for households in a block-group to occupy if their unit is damage, hence the more housing vulnerable.

some of which are related to addressing hazard/disaster needs. By identifying those focused areas within a community, planners can use these funding streams more effectively and efficiency to address the unique needs of their community's population.

Table 1. Social Vulnerability Indicators and 2nd and 3rd Order SV Measures

Base Social Vulnerability Indicators (percentages)	2nd Order	3rd Order
1. Single parent households with children/Total Households 2. Population 5 or below/Total Population	Potential Child care Needs	Socially Vulnerable Hotspot
3. Population 65 or above/Total Population 4. Population 65 or above & below poverty/Pop. 65 or above	Potential Elder Care Needs	
5. Workers using public transportation/Civilian pop. 16+ and employed 6. Occupied housing units without a vehicle/Occupied housing units (HUs)	Potential Trans. needs	
7. Occupied Housing units/Total housing units 8. Persons in renter occupied housing units/Total occupied housing units 9. Non-white population/Total population 10. Population in group quarters/Total population 11. Housing units built 20 years ago/Total housing Units 12. Mobile Homes/Total housing units 13. Persons in poverty/Total population	Potential Housing Needs (Temporary Shelter and housing recovery)	
14. Occupied housing units without a telephone/Total occupied HUs 15. Population above 25 with less than high school/Total pop above 25 16. Population 16+ in labor force and unemployed/Pop in Labor force 16+ 17. Population above 5 that speak English not well or not at all/Pop > 5	Potential Civic Capacity needs	

These basic indicators can in turn be combined to form 2nd order SV measures indicating special needs that are germane during emergency response, disaster recovery, or even when considering mitigation programs. In this case 2nd order measures were created to identify areas with higher potential for *child care needs* both before and after a disaster event, *elder needs* for evacuation and during the emergency response and long term recovery period, *transportation needs* particularly for hurricane and other types of emergency evacuation, *housing needs* or more specifically *temporary shelter and housing recovery needs* after a disaster, and *civic capacity needs* that can be particularly important during preparation, response, recovery, and mitigation. Any number of 2nd order SV measures might be created, depending upon the particular focus or emergency functions of interest. These composite scores can be created by adding or averaging proportions across block-groups. In this case we have computed average proportions.

Finally, all 17 indicators can be combined to form a composite *Social Vulnerability composite index*. To compute this measure we again simply averaged the 17 SV indicators with the resulting index offering a general measure of relatively high or low levels of social vulnerability. By focusing on the upper end of this composite index, planners and emergency managers can quickly identify a community's

hotspots or concentrations of higher levels of social vulnerability within and across block-groups. Of course, it is possible that a block-group may have very high proportions of socially vulnerable populations, say that over 80% of their population is elderly or non-white minorities, but there are very few actual people living in the block group itself. Block groups are constructed by the US Census to capture the population of individuals residing in these areas which generally range between a few hundred to several thousands.[6] To correct variability in population, a "weighted" SV measure can be calculated in which the score is either weighted based on a population size or density in the block-group. In this way, a block-group that has a high SV score and has a relatively large population or is very densely populated will score higher than one with a similar SV score but sparsely populated.

Table 2. Descriptive Statistics for 2000 Social Vulnerability Indicators, 2nd and 3rd Order *SV* Measures

Social Vulnerability Indicator, 2nd, or 3rd Order Measure	Mean	Median	Std.	Min.	Max.
1. Single Parent Households	10.69	9.43	7.80	0.00	63.67
2. Population ≤ 5 years	9.02	8.98	3.88	0.00	28.75
2nd Order: Potential child care needs	9.85	9.23	5.06	0.00	40.88
3. Population ≥ 65 years	11.43	10.08	6.96	0.00	52.42
4. Elders in Poverty	14.30	10.33	15.14	0.00	100.00
2nd Order: Potential elder care needs	12.86	11.69	8.14	0.00	54.62
5. Transportation dep. employees.	2.08	0.00	4.83	0.00	51.12
6. Housing units without auto	10.28	6.90	10.62	0.00	69.73
2nd Order: Potential transportation needs	6.18	3.92	7.04	0.00	58.82
7. Occupied housing units	89.00	91.73	11.17	0.00	100.00
8. Population in rental housing	35.13	30.91	22.77	0.00	100.00
9. Non-white population	53.97	53.25	30.95	0.00	100.00
10. Population in group-quarters	2.20	0.00	9.86	0.00	100.00
11. Housing over 20 years old	72.33	80.43	25.53	0.00	100.00
12. Mobile homes	6.46	0.20	11.59	0.00	81.61
13. Population in poverty	18.61	15.67	14.19	0.00	88.21
2nd Order: Potential housing needs	39.67	40.10	9.39	10.00	65.78
14. Housing units without phones	4.60	3.06	5.29	0.00	41.18
15. Pop. ≥ 25 w/o HS. diploma	30.50	27.00	19.45	0.00	100.00
16. Population ≥ 16 unemployed	8.90	7.08	7.57	0.00	100.00
17. Pop. not speaking English well	8.46	4.08	10.16	0.00	48.78
2nd Order: Potential civil capacity needs	13.12	11.13	8.79	0.00	42.09
Social Vulnerability	22.82	22.33	6.92	5.88	48.60

The data utilized in this report were drawn from the 1980, 1990, and 2000 U.S. Census data. A primary focus of this report will be to examine not only levels or current status of social vulnerability as measured by the 2000 census data, but to also examine changes and trends over this time period. We will begin our discussion however by focusing on the 2000 census data as an assessment of current status.

[6] The block groups for the first two tiers of states along the Texas coast have an average population of 1,614 individuals.

Table 2 displays the descriptive statistics for each of the 17 SV 1st order indicators, each of the five (5) second order SV measures and the total SV composite index for the 1,322 census block groups located in Texas's CMZ. Each second order SV measure is presented below its basic constituent indicators and is shaded in light orange. The final row in the table, this time shaded in a slightly darker orange, presents the statistics on the overall SV index that combines by averaging all 17 indicators. To ease in presentation, all proportions have been changed to percentages (by multiplying by 100).

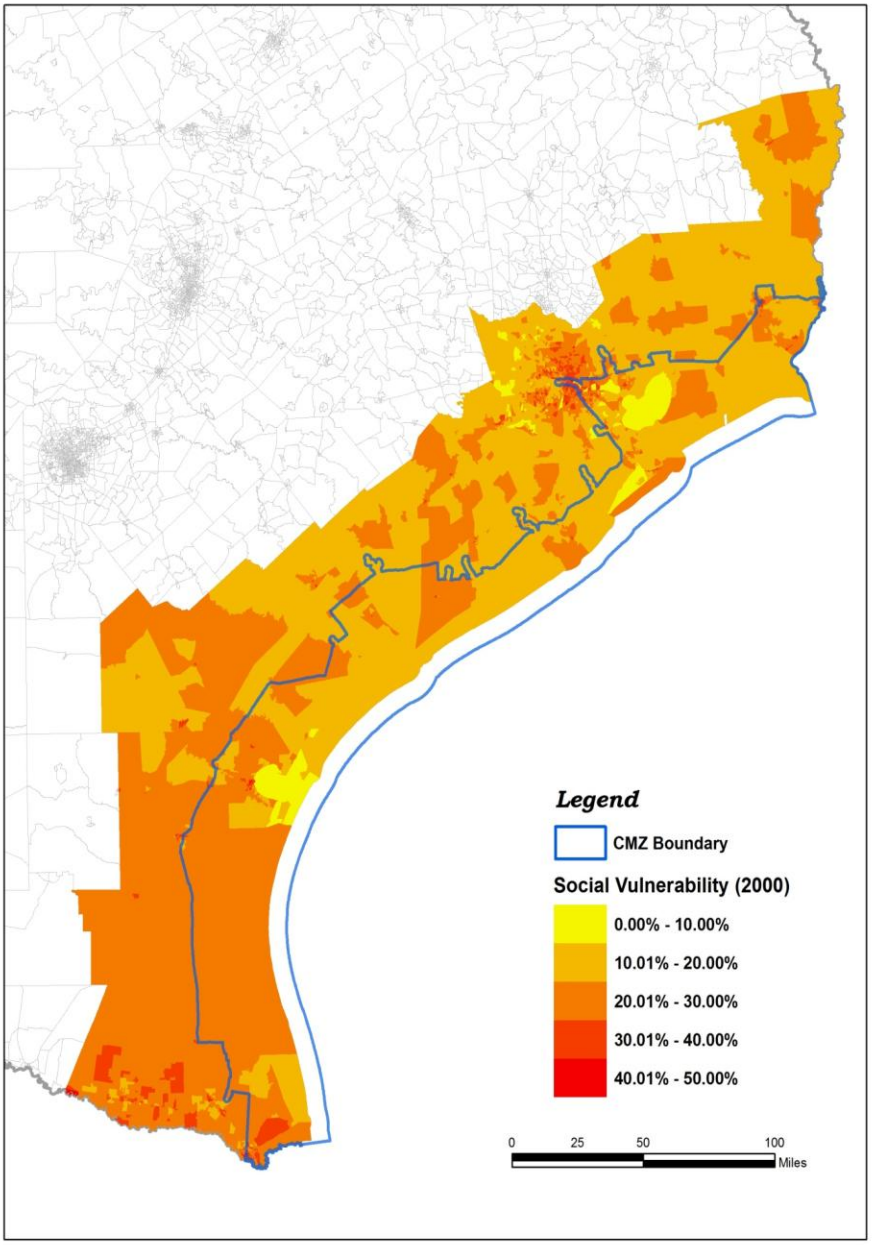
The basic SV indicators represent proportions, or in presentation, percentages, so the mean represents the average percentage across the 1,322 block groups in the Texas CMZ. For example, among CMZ block groups the average percentage of their households that are single parent households with children was 10.69%, with a median of 9.43%. The minimum percentage of these types of households across these block groups was 0, with a maximum of nearly 64%. There are a number of other descriptive statistics that are worth noting in this table. An average of just over 14% of all elders in these block groups are living below poverty levels. These block groups also have on average 10.28% of their households reporting not having their own vehicle for transportation and in at least one block group that percentage reaches nearly 70% of all occupied housing units. It is also very interesting to note that on average block-groups within the CMZ have populations that are nearly 54% non-white, with some block-groups composed of 100% non-white populations. As we will see below, this represents the changing population demographics of Texas. The average proportion of individuals living below poverty in CMZ block groups was 18.6%, with a high of 88.2%. The average proportion of populations over 25 without a high school degree was 30.5%, with a median value of 27%. Furthermore, while the average percentage of block group populations over 5 not speaking English well or at all was only 8.46%, the maximum for at least one was nearly 48.8%.

As can be easily seen in this table, the second order SV measures capture the average percentage across their component set of indicators. The final row presents the total *SV* measure or index, suggesting that the average vulnerability on a 100 point scale for the 1322 block groups located in the coastal management zone is nearly 23, based on this assessment of 17 indicators. Figure 6 offers a coastal wide map of the SV index results for 2000. This map clearly suggests that areas along the southern most coastal region of Texas have higher concentrations of vulnerable populations. Interestingly, the upper coast, while displaying some areas with relatively low levels of SV (note yellow areas), also contain pockets of higher levels of SV (darker orange).

As mentioned above, the 1st and 2nd order *SV* measures can be thought of as indicators of different dimensions of social vulnerability measured on, in this case, a scale that runs from 0 to 100. The overall SV index, on the other hand, yields a relatively coarse and quick assessment of levels of vulnerability considering multiple dimensions simultaneously. Before touching on various interpretations of

these measures, we continue with our general assessment of SV by examining of trends among the 1,322 CMS block groups.

Figure 6. Social Vulnerability Measure for the Texas Coast.



IV. Social Vulnerability Trends in the Coastal Management Zone

In this section we turn our attention to the patterns of social vulnerability from 1980 through 2000. Tables 3, 4, and 5 present the average vulnerability levels for the 17 1st order indicators, the five 2nd order measures, and for the overall *SV* composite index. In each case the average for the 1,322 CMZ block groups are presented for data from the 1980, 1990, and 2000 US Census. In addition,

differences between 1980 and 1990, 1990 and 2000, and 1980 and 2000 were computed and average difference scores are presented in the final three columns for each of these periods respectively. These differences are computed by subtracting the later percentage from the earlier percentage. Hence, negative values indicate that levels of SV are getting worse meaning increased in levels of social vulnerability, while positive differences suggest things are getting better meaning reductions in social vulnerability. Finally, each of these differences scores was tested to see if they were statistically significant from zero, implying no change. The results from these tests are also indicated with respect to each difference score.

Table 3: Average CMZ block group percentages and difference scores for 1980, 1990, and 2000 Child Care, Elder Care, and Transportation Needs.

Baseline Social Variables	Mean	Difference in Percentages[#]		
1. Single Parent Households	%'s	1980-1990	1990-2000	1980-2000
1980	6.77	-2.21**		
1990	8.98		-1.70**	
2000	10.69			-3.92**
2. Children five or below				
1980	10.33	0.99**		
1990	9.35		0.33**	
2000	9.02			1.32**
2nd Order: Child Care Needs				
1980	8.55	-0.61**		
1990	9.17		-0.69**	
2000	9.85			-1.30**
3. Elders (65+)				
1980	8.27	-2.28**		
1990	10.55		-0.89**	
2000	11.43			-3.17**
4. Elders living in poverty				
1980	9.47	-8.66**		
1990	18.13		3.83**	
2000	14.30			-4.83**
2nd Order: Elder Care Needs				
1980	8.87	-5.47**		
1990	14.34		1.47**	
2000	12.86			-4.00**
5. Labor force transportation. Dependent				
1980	1.78	1.47**		
1990	0.31		-1.77**	
2000	2.08			-0.30**
6. Households without a private vehicle				
1980	8.64	-2.10**		
1990	10.74		0.45*	
2000	10.28			-1.65**
2nd Order: Transportation Needs				

1980	5.21	-0.32***		
1990	5.53		-0.66**	
2000	6.18			-0.97**

 # statistical tests were all paired t-tests; * two tailed p<.05; ** two tailed p<.01;

Rather than discussing each of the 17 different SV indicators separately, followed by five (5) second order SV measures, and ending with a discussion of overall SV index trends, the following discussion will be structured on the basis of the 2nd order SV measures. In other words, each of the five (5) 2nd order SV measures – *potential child care needs*, *elder care needs*, *transportation needs*, *housing needs*, and *civil capacity needs* – along with their specific 1st order component indicators will be discussed. This in turn will be followed by the presentation of the overall SV index. Our discussion begins with *potential child care needs*.

1. Potential Child Care Needs: The percentage of single parent households with children increased throughout the period, beginning with an average across CMZ block groups of 6.77% in 1980, increasing to 8.98% in 1990 and finishing at 10.69% in 2000. Overall then, between 1980 and 2000 the average percentage of single parent households with children increased by nearly 4% points, which was statistically significant, suggesting increasing vulnerabilities on average across CMZ block groups. The average percentage of block group populations five years old or below --indicating very young and vulnerable children -- actually declined throughout the period. In 1980, on average just over 10% of block group populations were in this very young age group. However that percentage declined to just over 9% in 2000, yielding a net and statistically significant reduction over the period of 1.32%. While the average percentage of younger children did fall throughout this period, these reductions were offset by the increasing percentages of single parent households with children, resulting in an overall increase in potential child care needs from 1980 (8.55%) to 2000 (9.85%), yielding a negative change over that period of 1.3%, suggesting increasing vulnerabilities.

2. Potential Elder Care Needs: The trends for elders, elders in poverty and potential elder care needs are also presented in Table 3. As one might expect, given the general aging of the US population, the average proportions of elders, individuals 65 or older, in CMZ block groups generally increased throughout the period. In 1980 the average percentage was 8.27%, but that grew to 10.5% in 1990 and still further to 11.43% in 2000. The difference between the 1980 and 2000 proportion was a statistically significant -3.17%. This suggests increasing social vulnerabilities. The results with respect to elders living in poverty suggest some improvement between 1990 and 2000, however the net for the entire period suggest a net increase in SV. In 1980 on average 9.47% of elders in CMZ block groups were living below poverty levels. This average is nearly double by 1990 to just over 18%, but fortunately fell back to 14.3% in 2000. Nevertheless, on the whole the average difference between 1990 and 2000 percentages of block group elders residing in poverty was negative (-4.83%) suggesting an overall increase in social vulnerability with respect to this dimension. Overall then, the 2nd order elder care need measure, given the increase

in percentages of elder populations and elders living below the poverty level, increased from 8.9% in 1980 to 12.9% in 2000, resulting in a negative change of 4 percentage points, suggests increasing vulnerabilities with respect to elders over the period.

3. Potential Transportation Needs: Evacuation in particular, whether related to natural hazard or technical hazard events is dependent upon households and individuals to transport themselves out of the danger zone. Individuals or households without private transportation are at a distinct disadvantage when it comes to responding to evacuation "orders." Transportation can also be important for facilitating pre-event preparation and post event response. The trends with respect to transportation, like those for elders living in poverty, were not consistent, but the net differences again suggest increasing vulnerabilities. The average percentage of block group employed labor force dependent on public transportation actually declined precipitously between 1980 and 1990, moving from 1.8% to only .3% respectively. However this percentage also rose markedly by 2000 to 2.1%. The net effect was a small, but nevertheless significant, difference between 1980 and 2000 of -.3%, suggesting a slight increase in vulnerabilities. Interestingly the average percentage of households without private transportation was 8.6% in 1980, rose to 10.7% in 1990, and fell back slightly to 10.3%, resulting in a net difference between 1980 and 2000 of a significant -1.65%. The consequence of these two negative trends, results in an overall negative and statistically significant trend for transportation needs of just about -1%, suggesting that overall there is a slight increase in transportation vulnerabilities across CMZ block groups.

4. Housing Needs: Table 4 presents the seven (7) individual SV indicators and overall 2nd order measure related to potential housing needs. Housing needs indictors were selected because the literature suggests that they are related to emergency shelter and temporary and permanent housing needs following a disaster. The first indicator, occupied housing units, provides an indicator for potential surplus housing units that might, if occupied housing is damaged, provide for permanent or temporary housing needs after a disaster. In 1980 the average occupancy rate for CMZ block groups was nearly 90.2%, suggesting very little surplus housing. In 1990 the occupancy rate decreased to 86.3%, and then rose to 89% by 2000. Overall then, there was a slight, but significant, increase in surplus housing over the period, suggesting a potential reduction in housing need vulnerability. Unfortunately this was the only indicator that showed a net positive trend over this period.

The literature suggests that rental housing units are much slower to come on line after a disaster due to delayed rebuilding and repairs processes (c.f. Peacock, Dash and Zhang 2006; Zhang and Peacock 2010). These delays result in higher levels of population displacement after an event and slower recovery trends these for neighborhoods and communities. Hence, the higher the proportion of rental population, the higher the potential levels of temporary and long-term housing needs. In 1980 the average block group percentage of rental households was 34.7% that rose in 1990 to 36.6%, and then fell back slightly to 35.1%. The net change from

1980 to 2000 was not statistically significant. Essentially the overall average percentage of rental housing -- representing an average of slightly over one third of all housing – among CMZ block groups remained unchanged from 1980 to 2000.

Table 4: Average CMZ block group percentages and difference scores for 1980, 1990, and 2000 Housing Needs.

Baseline Social Variables	Average	Difference in Proportions[#]		
7. Occupied housing units				
1980	90.17	3.91**		
1990	86.26		-2.74**	
2000	89.00			1.17**
8. Households renting their residence				
1980	34.66	-1.96**		
1990	36.63		1.50**	
2000	35.13			-0.46
9. Non-white population				
1980	38.28	-7.12**		
1990	45.40		-8.56**	
2000	53.97			-15.69**
10. Population living in group quarters				
1980	1.22	-0.69**		
1990	1.91		-0.29	
2000	2.20			-0.98**
11. Housing over 20 years old				
1980	48.26	-10.30**		
1990	58.56		-13.78**	
2000	72.33			-24.08**
12. Mobile homes				
1980	5.34	-1.02**		
1990	6.36		-0.10	
2000	6.46			-1.12**
13. Population living in poverty				
1980	13.99	-6.65**		
1990	20.64		2.03**	
2000	18.61			-4.63**
2nd Order: Housing Needs				
1980	33.13	-3.41**		
1990	36.54		-3.13**	
2000	39.67			-6.54**

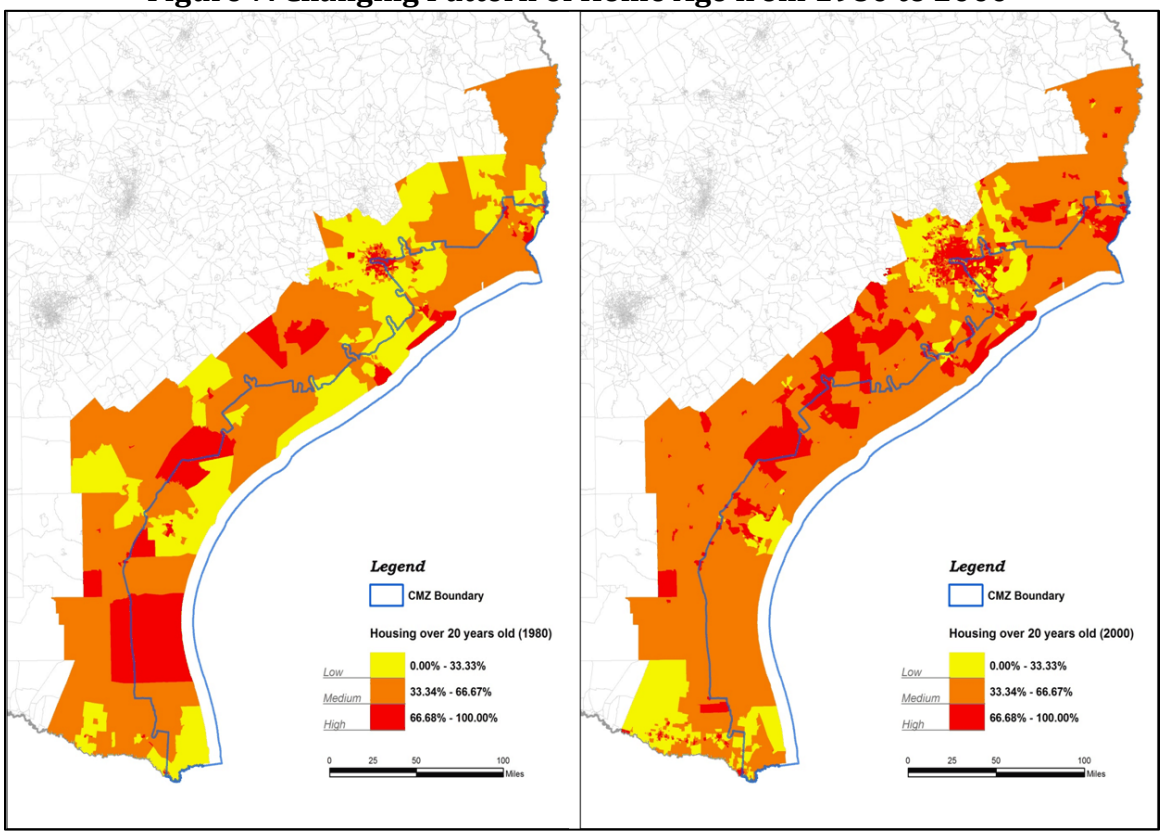
 # note all paired t-tests; * two tailed p<.05; ** two tailed p<.01; neg. values=more vulnerable; pos. values=less vulnerable

As discussed above, non-White populations are particularly sensitive to housing problems in the aftermath of natural disasters (Peacock, Dash, and Yang, 2006). The literature suggests that these populations are much more likely to be living in sub-standard housing and that housing is much more likely to be damaged in a disaster. Furthermore, non-White populations are more likely to have significantly reduced housing options when their homes are damage. Hence they are much more likely to need emergency shelter, temporary housing, and to have greater difficulty

establishing permanent housing after an event. In 1980 the average proportion of non-White populations across CMZ block groups was 38.3%, rose to 45.4% in 1990, and rose again to nearly 54% by 2000. This represents an average net increase in non-White populations of nearly 16%. This trend clearly suggests higher levels of social vulnerable populations within CMZ block groups throughout this period.

Populations in group quarters are generally individuals not related to each other residing together in both institutionalized and not institutionalized settings including jails, halfway houses, nursing homes, religious group quarters, college dormitories, etc. Often times, in these situations, special care is needed for evacuation and sheltering before and after an event. Furthermore, if housing is damage, the former occupants or their institutional guardians must make arrangements for temporary and, ultimately permanent housing. In 1980 the block group average for populations residing in group housing situations was 1.2%, that increased to 1.9% in 1990, and to 2.2% in 2000. The difference between 1980 and 2000 was approximately -1%, a statistically significant difference, implying increased vulnerability.

Figure 7. Changing Pattern of Home Age from 1980 to 2000



Housing quality and standards can have important consequences for disaster damage and hence both temporary and permanent housing needs after a disaster. The State of Texas has invested, through the Texas Department of Insurance (TDOI), to upgrade and improve building codes in Texas, particularly with respect to wind

standards. While Texas coastal communities have not been as quick to adopt these new standards as many would like, we have seen the slow improvement through time of building codes and standards as communities moved from the old southern building code to more recent versions of the International Building Code recommended by the TDOI. Furthermore, as one might expect some housing, for example site built housing, is more resistant to wind and flooding damage, than less permanent housing like mobile homes. To capture the relative vulnerabilities due these quality issues we have employed two measures: the percent of buildings over 20 years old and the percent of housing units that are mobile homes. In both case we can see trends toward higher vulnerabilities for housing in the CMZ. In 1980, on average 48.3% of housing was older than 20 years old in CMZ block groups. That percentage increased substantially to 58.6% in 1990, and 72.3% in 2000. These dramatic shifts can be easily seen in Figure 7 which clearly suggest average home age is increasing within the CMZ from 1980 to 2000. Indeed, the difference between 1980 and 2000 was -24.1% representing a significant increase in vulnerabilities. These changing patterns of housing age from 1980 to 2000 can be seen visually in Figure 7 above. While the average percentage of mobile homes was only 5.34% in 1980, it did increase to 6.46% by 2000, again increasing the average vulnerability for block groups in the CMZ.

The final housing needs indicator is the percent of a block group's population below poverty levels. The literature clearly suggest that poverty not only has consequences for anticipating and coping with natural hazards, but most importantly for housing, relative damage levels, and difficulty finding post disaster temporary and permanent housing (cf. Fothergill and Peek 2004, Peacock, Dash and Zhang 2006). In 1980 an average of nearly 14% of block group populations were below poverty levels. In 1990 the average rose to 20.6%, but fortunately fell back slightly to 18.6% by 2000. Nevertheless, the net average difference between 1980 and 2000 was a negative 4.63. Again this was a significant increase in the levels of social vulnerability, related to poverty across CMZ block groups.

On the whole then, for 6 of the 7 housing needs indicators the net trend was toward increasing social vulnerability. It should not be surprising then that the combined SV measure for *potential housing needs* shows a consistent and significant increase between 1980, 1990 and 2000. Indeed the net difference between 1980, at 33.13%, and 2000, at 39.67%, is a significant -6.54%. This negative value, again suggests that social vulnerabilities with respect to housing has increased on average across all blocks within the CMZ.

5. Civil Capacity: The final set of SV 1st order or basic indicators and their 2nd order measure seeks to capture the *civic capacity needs* of a block group's population. One of the often cited critiques of vulnerability analysis is the failure to address the inherent capacities of even the most vulnerable communities to martial their limited social, human, and economic capital resources to address hazard risks and disaster impacts. In an attempt to address this critique, our approach seeks to directly address these capital features of a block group's population. The ability to share

information and communicate with others, particularly those within ones social network can be extremely important for the dissemination of warning and mitigation information, as discussed above. To partially capture this ability we include a measure of the percent of a block group's households without telephones. In 1980 the average percentage of households without access to a phone was 10.56% and that percentage increase to 10.79% in 1990. However, by 2000 this percentage fell markedly to only 4.6%, probably due to the proliferation of relatively low coast cellular phone technologies. Indeed, the difference between the percent of households without phone access between 1980 and 2000 was +6.04 percentage points suggesting increasing capacities to communicate among family, friends and associated networks, resulting in an overall decline in social vulnerability.

Table 5: Average CMZ block group percentages and difference scores for 1980, 1990, and 2000 Housing Needs.

Baseline Social Variables	Ave.	Difference in Proportions[#]		
14. Households without a telephone				
1980	10.65	-0.15		
1990	10.79		0.23**	
2000	4.60			6.04**
15. Population over 25 w/o high school degree				
1980	40.00	5.84**		
1990	34.16		3.66**	
2000	30.50			9.50**
16. Labor force unemployed				
1980	5.21	-3.74**		
1990	8.94		0.05	
2000	8.90			-3.69**
17. Population over 5 not speaking English well				
1980	2.59	-3.85**		
1990	6.44		-2.02**	
2000	8.46			-5.87**
2nd Order: Civic Capacity needs				
1980	14.61	-0.47**		
1990	15.09		1.97**	
2000	13.12			1.50**
3rd Order: Social Vulnerability				
1980	19.74	-2.27**		
1990	22.01		-0.81**	
2000	22.82			-3.08**

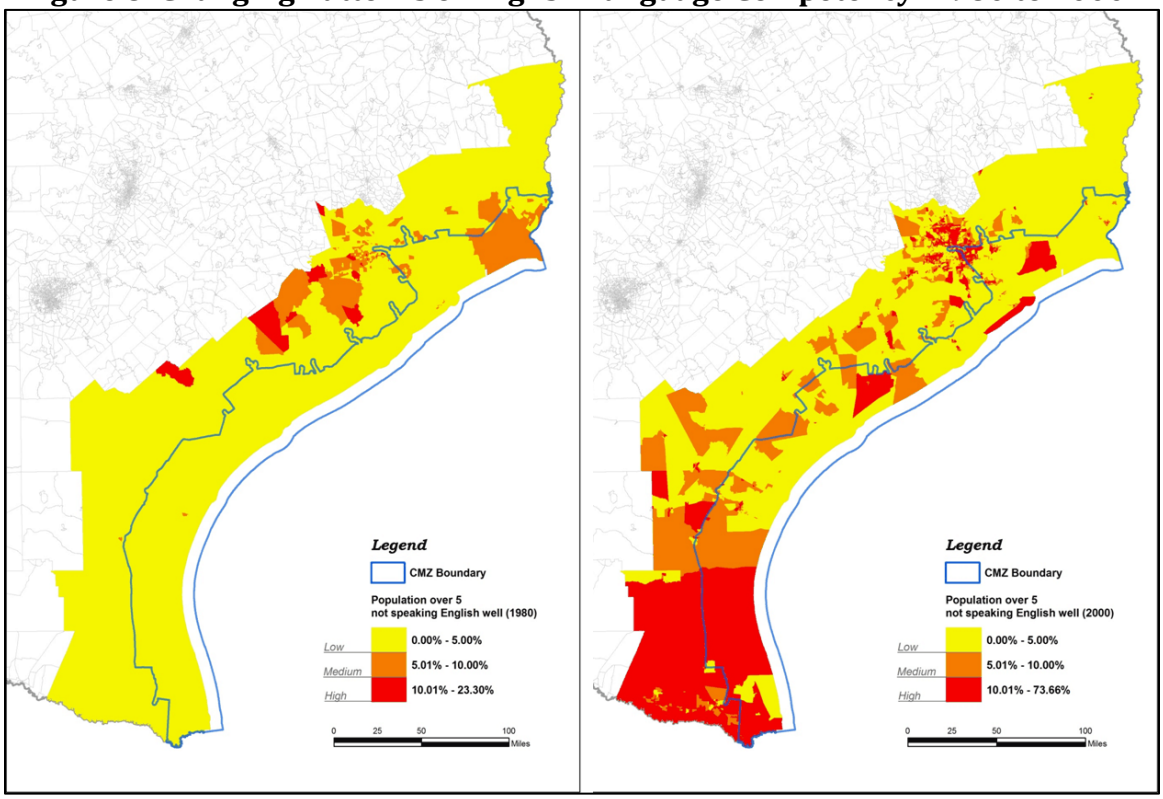
 # note all paired t-tests; * two tailed p<.05; ** two tailed p<.01; negative = more vulnerable; positive = less vulnerable

A similar pattern emerges when examining the average percentages of individuals over 25 without a high school diploma or equivalent, a measure of the community's human capital. In 1980 the average percentage was 40%, but by 1990 that percentage fell to 34.2% and it fell even further by 2000 to 30.5%. Between 1980 and 2000 then, there was a vast and significant improvement of 9.5 percentages

points. In other words, the average the human capital assets – measured in terms of achieving a high school diploma -- of CMZ block groups increased. As a consequence, their relative social vulnerability actually fell during the period of 1980 through 2000.

The patterns with respect to the last two civic capacity need measures – unemployment and English competency – unfortunately do not exhibit the same trends as the first two indicators. In 1980 the average unemployment rate across CMZ block groups was 5.21%, in 1990 the rate increased to 8.9% and it remained essential unchanged by 2000. The net trend between 1980 and 2000 was therefore a significant increase in unemployment of 3.69 percentage points, suggesting less economic capital assets, in the form of wages and salaries, for populations to draw upon. Similarly, in 1980 only 2.59% of the population over 5 did not speak English well or at all, in 1990 that percentage rose to 6.44% and by 2000 it rose still higher, finishing at 8.46%. Thus, with respect to English language competency, on average, CMZ block groups actually experienced a significant reduction in competency of -5.87 percentage points, suggesting an increase social vulnerability over the period. These changing vulnerability patterns are quite pronounced and can easily be seen in Figure 8. The CMZ block groups have substantially change between 1980 and 2000, with many block groups now having substantial percentages of individuals with limited English speaking competency. Despite these trends with respect to unemployment and language competency, the overall civic capacity levels actually improve.

Figure 8. Changing Patterns of English Language Competency: 1980 to 2000.



With respect to civic capacity, we see two very different trends, while fewer households are without a phone and more adults have a high school degree or equivalent, unemployment rates have increased and so has the proportion of the population without English speaking competency. On the whole, the 2nd order civic capacity needs measure actually deceases over the period moving to 13.12% in 2000 from 14.6% in 1980, resulting in a significant, 1.5 percentage point improvement and a reduction in *civic capacity needs*.

6. Overall Social Vulnerability: Despite the reduction in SV with respect to *civil capacity needs*, and reductions in 5 of the 17 SV indicators during the period of 1980 to 2000, on the whole the average level of *Social Vulnerability* as measured by the SV composite index has actually grown for block groups within the coastal management zone. The bottom most sections of Table 5 present the summary statistics for the overall *SV index,* which again is the average for all 17 1st order SV indicators. In general, the SV level was 19.7% in 1980, rose to just over 22% in 1990, and then finished the period at 22.8%. The net difference score between 1980 and 2000 was -3.1%, which again is statistically significant and indicates an increase in overall average levels of *social vulnerability* across all CMZ block groups.

It must be remembered the general *SV composite index* is more of a coarse and relatively quick assessment across all of the 17 indicators or dimensions of vulnerability. So for planners and emergency managers, this measure provides a general assessment of SV levels and an indication of areas likely to have concentrations of highly vulnerable populations. Regardless of which SV measure is employed, there is no magic number or level, beyond which one can easily suggest that the population of a given block groups "is" or "is not" socially vulnerable. Rather these are relative indicators. They assess a particular characteristics, dimension, or set of characteristics of a block group's population. When applied to a region, like the coastal management zone, they provide a picture of a region's block groups in terms of the ability of their population's to respond, anticipate, and recover from a natural disaster or hazard threat. Any level of SV should be of some concern for planners and emergency managers, in that it suggests that components of their community's population may have difficulty responding to hazard threats and recovering from disasters. Furthermore, relatively higher levels of SV suggest the need for special attention and perhaps working on particular policies, activities, education programs or other organizational responses to help those areas or neighborhoods to better respond and meet future hazard events.

As it stands now, with respect to our measurement and the simple analysis strategy we have undertaken here, we can see that, with respect to 17 separate indicators of SV, populations within the 1,322 coastal management zone block groups are becoming more vulnerable with respect to 12 of the 17 different SV indictors. Specifically, we see that on average block group population have higher percentages of single parent households, elder populations, elder populations living in poverty, labor force dependent on public transportation, households without private

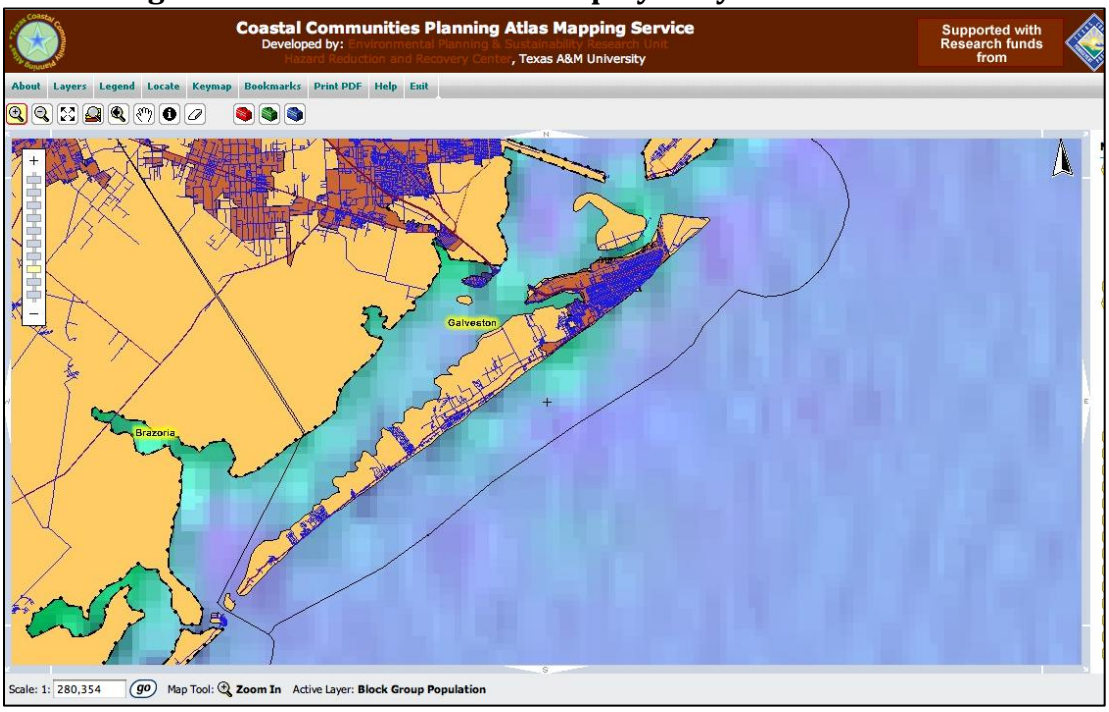
transportation, households renting, non-white populations, populations in group quarters, populations living in older housing and mobile homes, individuals livinb below poverty, unemployed and populations not speaking English well. On the whole, it is important to note that we do see some improvement in overall civic capacities of these populations. Nevertheless, we also see trends suggesting greater hazard and disaster needs with respect to transportation, housing, and child and elder care needs. These are important trends for hazard planning and emergency management in Texas.

Having examined the logic behind social vulnerability mapping, discussed the methods and details followed in creating the SV mapping approach adopted and utilized in the *coastal planning atlas*, and discussed the status and trends in dimensions and overall levels of SV for the Texas coast, focusing on the CMZ, we now turn out attention to a brief assessment of the relevance of social vulnerability mapping for hazard and disaster issues in Texas. Specifically, we will utilize the example of Hurricane Ike, how people responded to the threat it posed by evacuating and Ike's impact on Galveston and the recovery process for this assessment. But before doing that, the following section provides a brief discussion of Galveston, some examples of SV maps for the Island, and Hurricane Ike.

V. Galveston and Social Vulnerability

Galveston is one of the most urbanized barrier islands in the United States (see Figure 9). Although the City's population is declining only in part because of the hurricane (just under 50,000 following Hurricane Ike), growth in the region has been rapid. The Island itself has a dense urban core on the east end of the island, where 89 percent of the population lived in 2000. The sprawling west end of the Island is home to the remaining 11 percent of the population and one additional smaller incorporated community, Jamaica Beach. In addition to much higher population densities, the urban core also has higher occupancy rates (85 percent, compared to 47 percent on the West End), and higher home ownership rates (60 percent, compared to 46 percent on the West End).

Figure 9: Galveston Island as displayed by the Coastal Atlas.



Not surprisingly, given that Galveston is a barrier island, the Island is highly vulnerable to coastal hazards like hurricanes. Figure 10, for example, zooms in on the urban core of Galveston City and displays surge zones for category 1 (red), 2 (orange), and 3 (blue) hurricanes. When Hurricane Ike passed over the Island, as can be seen in Figure 11, the urban core was protected from powerful surge flows and destructive wave action coming from the ocean side by Galveston's famous seawall constructed after the 1900 storm. Nevertheless, given the circulation of the storm, which was counter clockwise, the storm pushed part of its storm surge onto the island from the backside. As a consequence, the surge entered the urban core from the bay side, flooding many areas designated as category 1 and 2, as well as substantial proportions of category 3 areas. Category 1 and 2 areas are substantially lower and thus homes and businesses structures in those areas were subject to extensive flood waters prior to the storm passing over the Island and extending for many hours after it passed.

Figure 10. Category 1, 2 & 3 Hurricane Surge Areas

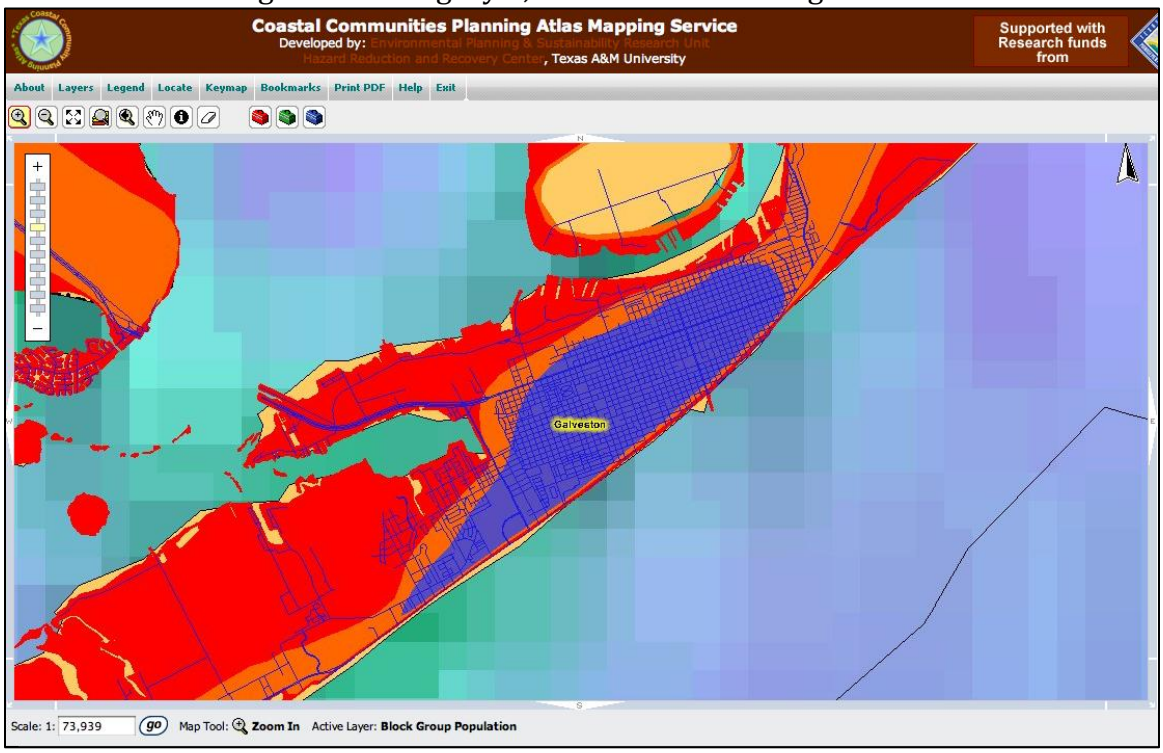
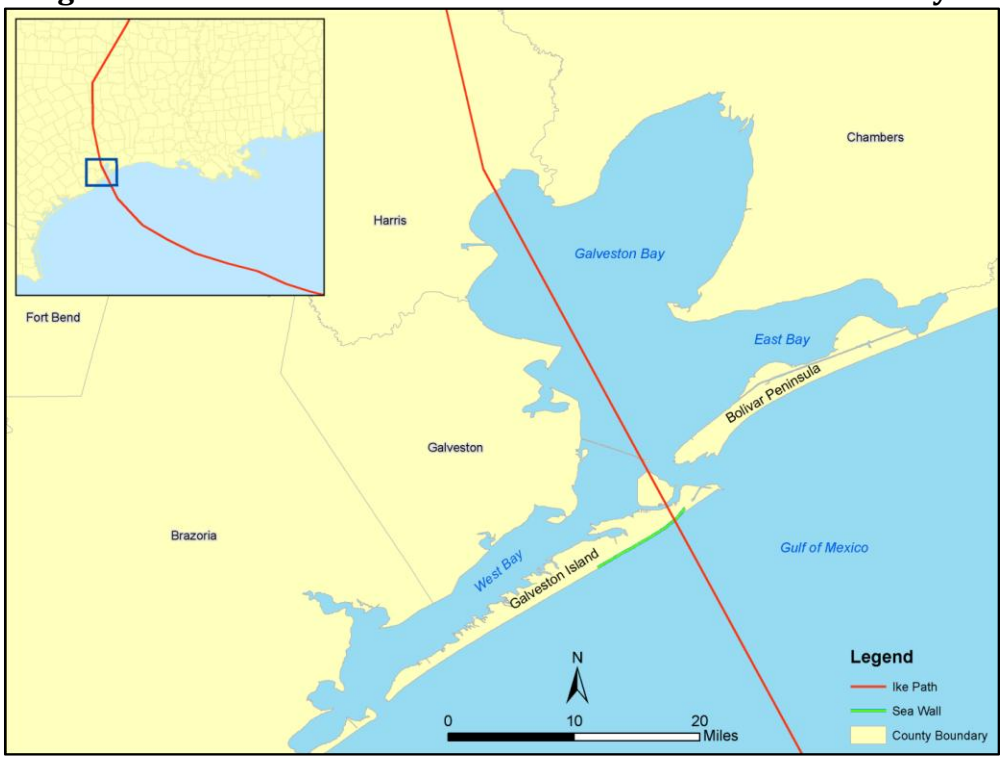


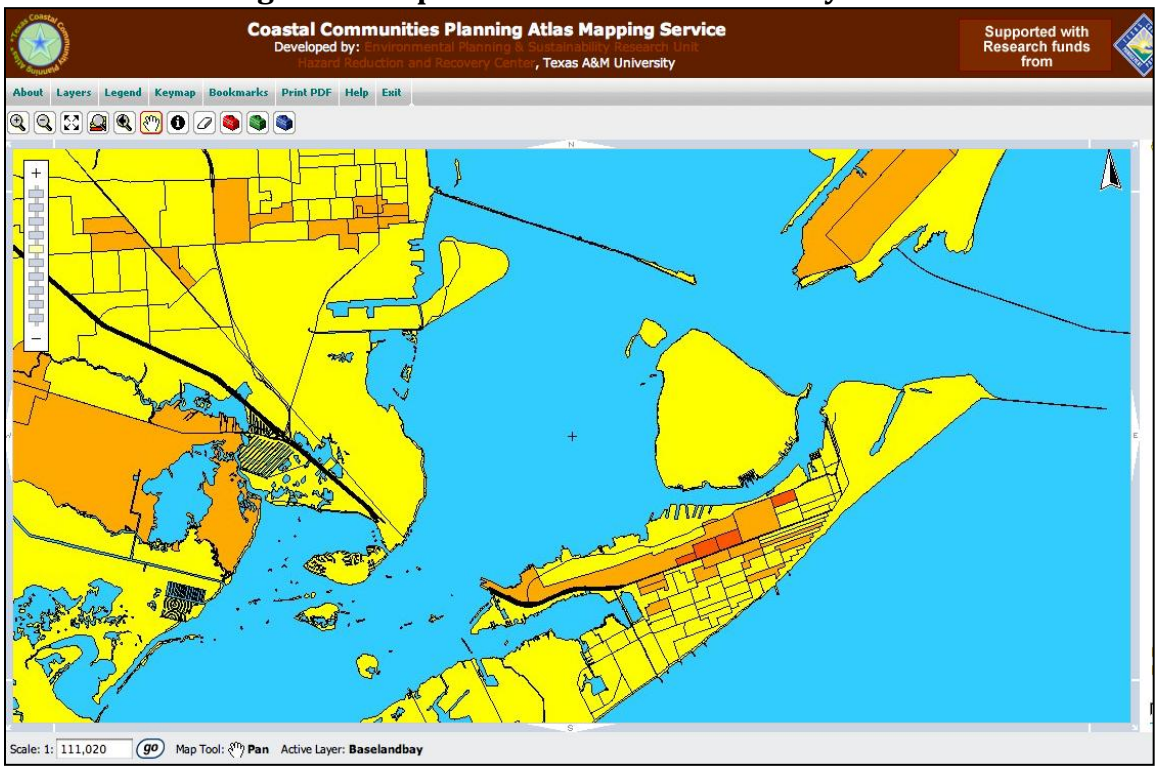
Figure 11. Galveston Island with the Path of Hurricane Ike's Eye.



Like most cities, housing in the dense urban core is much older and generally in much poorer condition. Not surprisingly, this area also has a much more diverse

population, with higher concentrations of minorities and households living in poverty. In other words, there are higher concentrations of socially vulnerable populations found in the urban core of the Island. Figure 12 displays SV block group data for the Island, as well as mainland sections of Galveston County, indicating concentrations of individuals living at or below the poverty line. As can be seen in this figure, there are a number of block-groups that have relatively high concentrations of individuals living below the poverty line that, as seen in Figure 12, are also located in areas vulnerable to surge inundation.

Figure12: Population At or Below Poverty Level



The real benefit of tools like the *coastal planning atlas* for planning purposes and for helping citizens better understand their risk, is being able to identify areas that are *both* physically and socially vulnerable by overlapping these data. This also allows the identification of critically vulnerable areas and hence important targets for the focus of emergency management and mitigation activities. Figure 13, for example, displays areas with high concentrations of non-white populations that are also subject to category 1 and 2 storm surge. In light of the literature that suggest that these populations are less trusting of authorities when it comes to heeding warning, and are more dependent on social networks, local emergency management and planning officials might develop special relationships with churches and civic organizations in these areas to better insure that when official warning are released, these organizations can reinforce the warnings through informal networks, thereby enhancing timely compliance.

Figure 13. Non-White Population Concentration and Category 1 & 2 Surge Zones

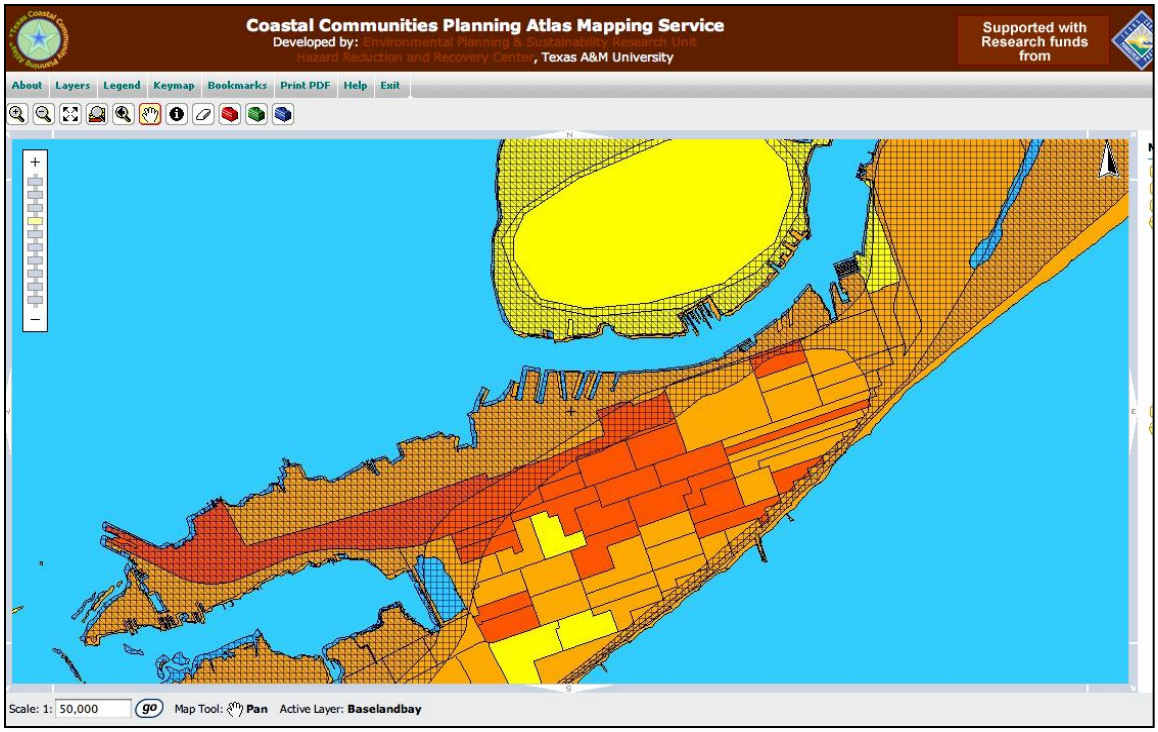


Figure 14. Weighted SV Composite measure and Category 1 & 2 Surge Zones

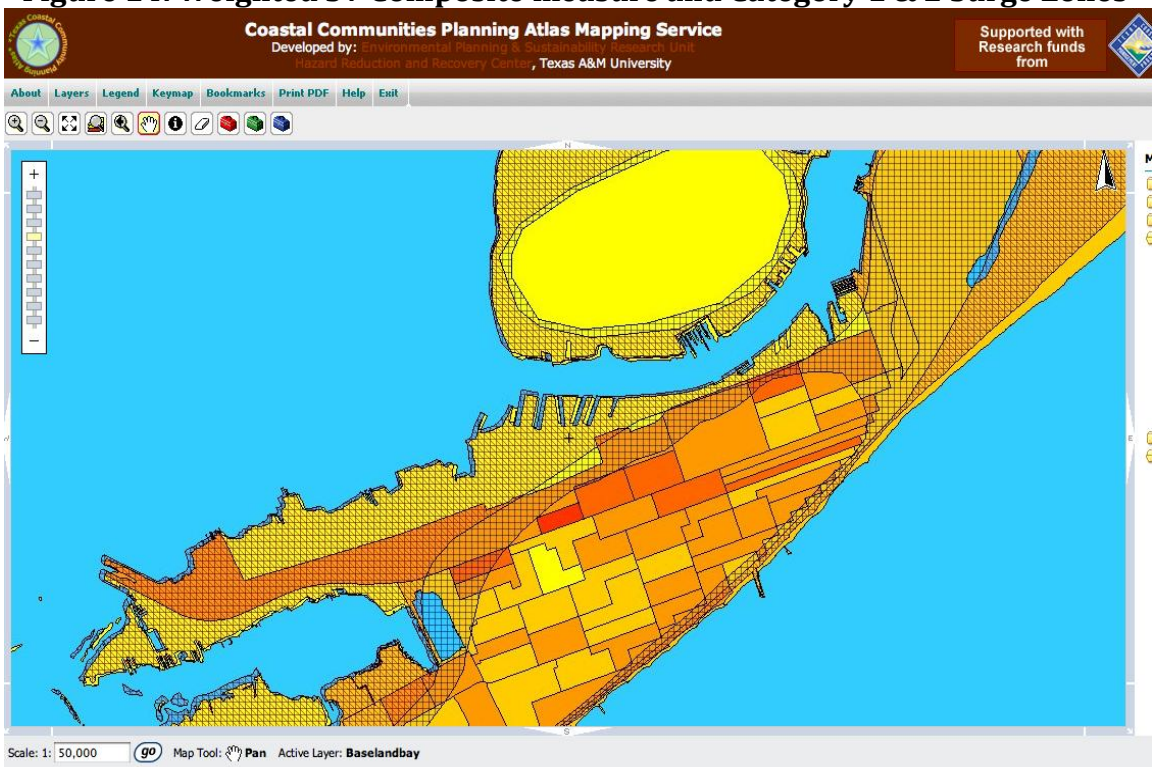


Figure 14 displays the SV composite measure, which in this case has also been weighted by population densities in Galveston County, overlaid with category 1 and 2 surge zones. As discussed above, the SV measure is particularly useful for quickly identifying areas that have concentrations of socially vulnerable populations. In this case the additional weighting also helps to identify areas with high population concentrations as well. The areas that are darker orange will be areas that urban search and rescue as well as emergency health officials will want to quickly visit after a disaster to determine if there are stranded individuals or individuals needing special medical attention.

VI. Findings from the Hurricane Ike Research

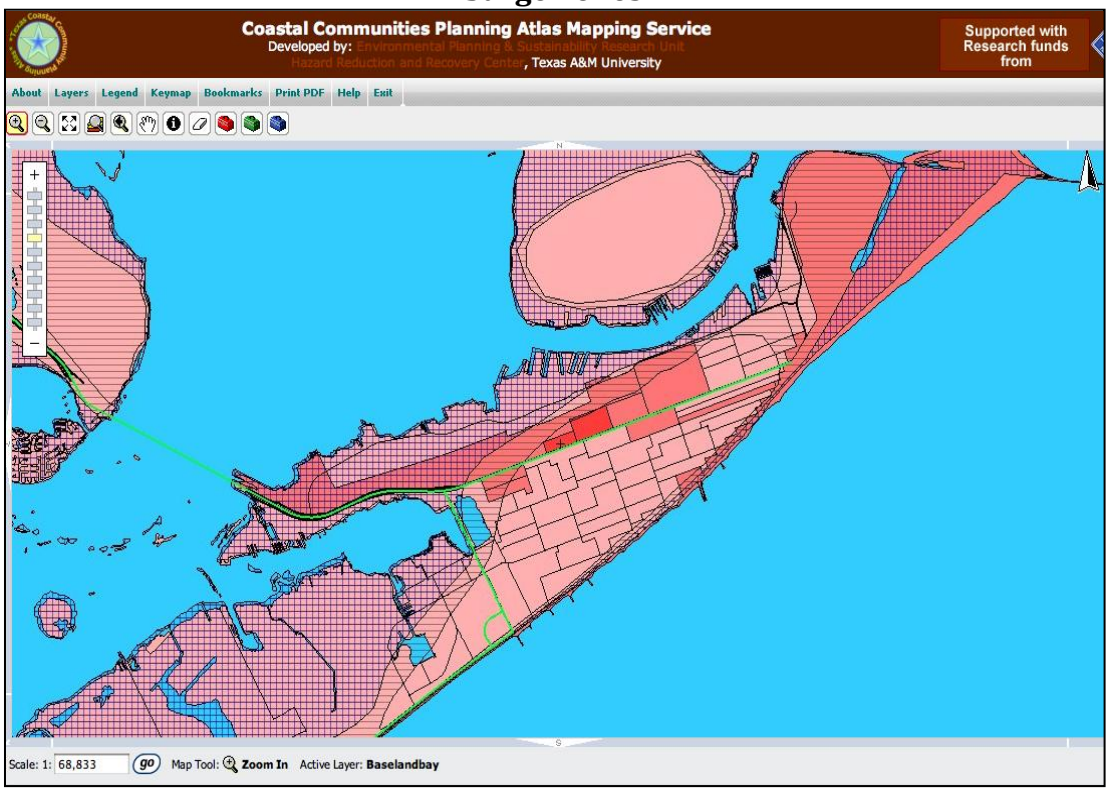
Hurricane Ike provides an opportunity to assess how well the mapping of social vulnerability characteristics in the Coastal Atlas can assist local emergency management and planning departments to identify areas such as neighborhoods containing households and individuals that will have greater difficulty responding to and recovering from similar disaster events. In this section, we present examples of how social vulnerability characteristics are related to the response, impact, access to recovery resources, and the initial stages of the recovery process. In undertaking this assessment, we must be careful to acknowledge that every disaster event and the community impacted will have their own unique qualities. Consequently, this does not necessarily represent a critical test of the utility of social vulnerability mapping as a tool for planning. Nevertheless, we should generally expect to find patterns that are consistent with the research literature on SV. In this case we will use data collected from both primary and secondary sources in the months immediately after the storm to see if the patterns anticipated by the literature and identified by the SV mapping approach hold.

In December 2008, eighteen students and four faculty members from the Hazard Reduction & Recovery Center at Texas A&M University spent approximately 2,000 hours on Galveston and Bolivar Islands, collecting approximately 1,500 damage assessments and completing more than 550 household surveys from a random sample of 1,500 detached (single family) housing units. Damage assessments determined the structural characteristics of the housing unit as well as visible evidence of damage. Household surveys asked respondents to assess their own level of damage, and also asked a series of questions about evacuation, recovery resources, and early decision-making with regard to returning to the Island to rebuild. These data will be utilized in this report along with secondary data. Specifically, we also draw on data from the City of Galveston on building permits granted in the months after the storm and tax assessments. These data help us to assess the value of the damage sustained, as well as the timing and volume of repairs undertaken to impacted properties. Because these permits are geocoded by property ID number, we are able to match them to our primary datasets, as well as assess variation by spatial location.

Together, these data give a fairly comprehensive view of the response from residents of detached, generally speaking single family, housing units to the Hurricane. Unfortunately, these data do not include residents of multi-family structures, which are home to a population that is likely to be particularly vulnerable, since they are almost exclusively renters. Along with the vulnerabilities associated with renting discussed earlier, renters are also more likely to be non-white and poor, which likely exacerbates their vulnerability. As a result, these findings likely underestimate the true incidence and consequences of social vulnerability among Galveston residents.

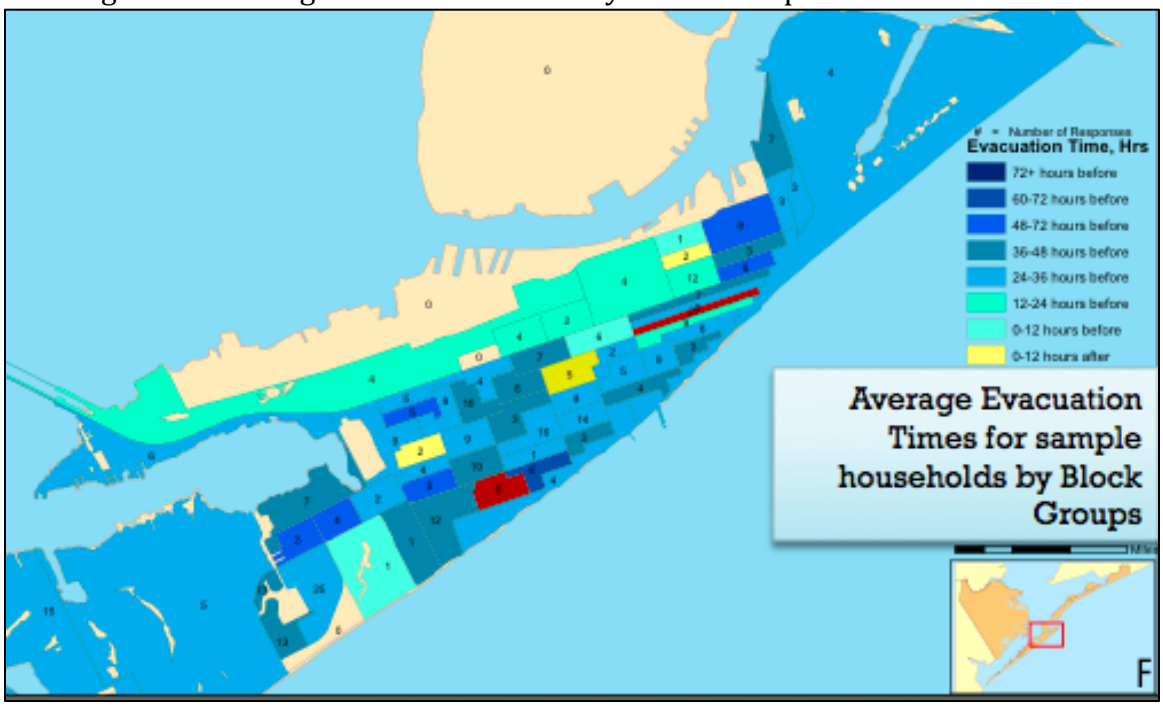
There are a variety of approaches that could be used to assess the correspondence or relationships between SV measures and response, impact and recovery outcomes. A simple but limited approach might be to compare SV maps to outcome maps and look for commonalities in patterns. For example, Figure 15 displays the 2nd order SV measure for *transportation needs*, identifying block-group concentrations of households without access to their own vehicles and with workers dependent upon public transportation. Figure 16 displays average evacuation times by block group for the same area. It would be anticipated that areas with high concentrations of individuals and households with transportation issues would have greater difficulty evacuating and hence leave later in the process.

Figure 15. Block Groups with High Transportation Needs & Category 1 & 2 Surge Zones



By comparing the two maps, a general overall pattern of correspondence between high transportation needs and late evacuation times can be roughly seen. This pattern is most clearly evident if one notes that areas in darker pink colors in Figure 15, indicating higher transportation need concentrations and hence transportationally challenged populations, are also the same areas in Figure 16 that have lighter blue colors indicating that they were on average later to evacuate in response to warnings and official evacuation calls. This pattern suggests that households without access to private transportation do seem to be related to later neighborhood evacuation times. Hence, focusing planning activities to ensure that populations without their own transportation have a way of evacuating earlier could well reduce the vulnerability of these populations.

Figure 16. Average Evacuation Times by Block-Group for Galveston Island



While assessments based on the comparisons of maps offer a visual method of determining correspondence, they are also highly dependent upon the patterns evident for a few block-groups and not the overall pattern displayed across all block group observations. In other words, they are too subject to perceptual biases. As a consequence, a more robust yet simple statistical technique will be employed. To assess the relationship between social vulnerability characteristics and hurricane response, impact and recovery, we use simple correlations. As discussed above, the SV indicators are based on 2000 U.S. Census data measured at the block group level. While hurricane response, impact and recovery are measured at the individual household or housing unit level, they too can be aggregated to the block group level by calculating appropriate summary statistics. These assessments, then, will be based on the correlations between these two sets of measures at the block-group level for Galveston Island.

Before proceeding, it is necessary to offer again a cautions statement about this analysis. As noted above, each disaster and community is unique, hence in a very real sense this is simply a case study as to whether or not we see relationships between SV measures and selected disaster response and impact assessments gained from data collected following hurricane Ike. In addition, as noted above, we will be aggregating individual level data from our surveys and secondary sources to the block group level to undertake the analysis. Aggregation of these data to the block group is not without problems. Most of our data come from a random sample of 1500 single family structures that was not designed to ensure equal or representative sampling of homes or households within block groups. As a result, some block groups will have more sampled homes/households than others and these single family sampled might better capture the nature of housing and households within some block groups better than others. Indeed, a closer examination of Figure 16 actually shows the number of households providing data on evacuation times for that each block group in that map. While some block groups have 10, 12, or even 20+ observations upon which to base an aggregation (i.e., upon which to calculate block group statistics), others have as few as 1, 2 or 3. This means that the aggregation will not be as precise or representative as is possible in many cases and will introduce additional random noise into our analysis.

The net effect will mean that this analysis should not be considered a critical test. Indeed, in many respect this test is stacked against finding significant results because our estimations will be less precise. Nevertheless, they do offer us some ability to assess the potential utility of using SV mapping approaches to understand disaster responses and impacts, and thereby help guide hazard and disaster planning. With this caution in mind, we now turn our attention to this assessment of the relationship between aggregate SV measures and various measures of disaster response, damage, and initial levels of recovery. Our analysis begins with evacuation.

Evacuation: In the hours preceding landfall, residents received continual information related to hurricane warning and watches and local emergency management (the Galveston County Judge) called for all residents to evacuate the Island. Most responded; our data indicate that approximately 80 percent of the population evacuated from the Island. Table 2 shows correlations for the social vulnerability indices, base indicators, and second order indices with the percent of sampled block-group households that evacuated and the average block group evacuation time measured in terms of how many hours before landfall households evacuated. In general our expectations, based on the literature, will be that areas with higher concentrations of socially vulnerable populations will show lower rates of evacuation and when they do evacuate, the expectation will be that they will have later evacuation times. The findings in Table 6 are generally consistent with the SV expectations. Here we see that the composite SV measure is negatively associated with evacuation, indicating that areas with highly vulnerable households saw relatively lower evacuation rates and the average evacuation times for those that did evacuate were later or closer to actual landfall.

Table 6. Correlations between SV indicators and Evacuation Response Data

	Evacuated	Evacuation time
SV Composite Measure	-.2463**	-.2909**
1st Order or Base Indicators		
Percent Single parent households with children	-.3021**	-.1618
Percent population 65 or older	.1124	-.1557
Percent Elders below poverty level	-.0900	-.0686
Percent employed dependent on public transportation	-.1961*	-.1893*
Percent occupied housing units without a vehicle	-.2380**	-.1763*
Percent population in renter occupied housing units	-.3776**	-.2499**
Percent non-white population	-.2231**	-.2532**
Percent pop. group housing	-.2041**	-.0348
Persons in poverty	-.2265**	-.2244**
Percent occupied housing units without a telephone	-.1284	-.1591
Percent population 25 or older w/o high school	-.1641	-.1330
Percent labor force unemployed for age above 16	-.0679	-.2303**
Percent 5 or older not speaking English well or not at all	-.1016	.0180
2nd Order Indices		
Public transportation needs	-.2492**	-.1962*
Civic capacity	-.1670*	-.1838*

Note: * indicates one-tail p≤.1; ** one-tail p≤.05.

Base level indicators help us understand the contributors to this overall relationship. Results indicate that neighborhoods with higher percentages of single parent households, renters, households in poverty, and non-white households experienced lower evacuation rates. Not surprisingly, areas with higher concentrations of households without a vehicle and with workers dependent upon public transportation also saw lower evacuation rates. Many of these same vulnerabilities were associated with later evacuation times. Specifically, neighborhoods with higher proportions of renters, households in poverty, and minorities were more likely to have gotten off the island closer to the arrival time of the storm, which greatly jeopardized their evacuation, since water began creeping on the Island well in advance of the storm's impact, cutting off many evacuation routes. In addition, areas with higher percentages of occupied housing without vehicles and with workers dependent on public transportation left later as well, although these coefficients were only marginally significant.

These second order measures are useful from a planning and management perspective, as they relate to different types of assistance, funding sources, or needed improvements. They also capture the compounding effects of dimensions of SV that can exacerbate abilities of individuals and households in an area to respond

to disaster threats. In this case, two 2nd order indicators are examined: transportation needs and civic capacity needs. The former is associated with household ability to evacuate, which as noted above is highly dependent upon privately owned transportation. The latter, composed as it is of measures related to communication, education, employment, and language skills, assesses the neighborhood's human capital. In this case a lack of transportation is a clear and significant obstacle to evacuating—neighborhoods with high proportions of households without access to private transportation and dependent on public transportation off the Island (which is quite limited in the first place) had lower evacuation rates and, while only marginally significant, these areas had later average evacuation times. Similarly, areas with higher civic capacity needs saw lower evacuation rates and later evacuation times, although again, these correlations are only marginally significant.

Damage: The most visibly devastating impact of the storm is the damage to physical structures; in particular, homes. As with most hurricanes, the damage comes in two forms: wind and water. In Galveston Island's case, the wind damage was fairly minor and limited. The real damage came from the storm surge, which washed back across the Island from the Bay side. As a consequence, the surge that impacted most of the Island's urban core was not the powerful Gulf surge seen on the Bolivar Peninsula, nor was it accompanied by the damaging effects of wave action that destroyed homes and scoured away whole structures and their foundations. Rather it was characterized by slow rising waters as the Bay crept on to the Island into the urban core area, filling the city with water. As a consequence, it was somewhat difficult to assess water damage from outside the home.

In Table 7, different measures of damage are employed. The first, overall damage, relies on an assessment by field researchers of visible external damage to the structure. The second and third columns rely on assessments by the survey respondents (household occupants) themselves, of overall damage and of internal damage that would may have been visible to the field researcher. All three of these measures generally assess the relative extent or percent of damage suffered by the home externally and internally. The last two columns are based on the assessed "improved" (the value of the building on the property) property values for 2008 and 2009. The 2008 property assessment reflected the property's structure or home value prior to the hurricane and the 2009 reflected the value of the damaged structure. We computed the absolute loss in the structures value and the percentage loss in the structure. With respect to all of these measures, averages were computed for all surveyed or, in the case of the property value data, for all single family homes in each block group to give an overall damage assessment for the block group or neighborhood. Given the SV research which generally finds that socially vulnerable populations experience greater *relative* losses but lower *absolute* losses, our expectations are that areas with higher concentrations of SV should be positively associated with the relative damage measures (the 1st, 3rd, and 5th columns), but be negatively associated with absolute loss (the 4th column).

Table 7. Correlations between SV indicators and Damage Data

	Overall damage	Self-assessment of overall damage	Self-assessment of Internal Damage	Absolute value loss	Percent value loss
SV Composite Index	-.0277	-.1213	-.0039	-.3274*	.1368
1st Order or Base Indicators					
Percent population 65 or older	-.0599	.0588	.0688	-.1086	-.0446
Percent Elders below poverty level	-.0789	-.1630	-.0602	-.2892*	-.0035
Percent pop. in renter occupied HUs	-.0085	-.1293	-.0601	.0757	.0661
Percent non-white population	.0516	-.0977	-.0083	-.2761*	.2548*
Housing units built 20 years ago	-.1934	-.1525	-.0314	-.4407*	-.0376
Percent mobile homes	.2615*	.2091	.1848	-.0757	.5611
Persons in poverty	-.1243	-.1130	-.0312	-.2044	.1057
Per. occupied HUs without a telephone	.0131	-.0442	-.0316	-.3520*	-.0348
Per. pop. 25 or older w/o high school	.0393	-.1881	-.0908	-.5208*	.0263
Per. labor force unemployed	-.0597	.0355	.1097	-.2088	.0479
Percent ≥5 yrs. w/o English competency	.1426	-.1597	-.0487	-.2705*	.0723
2nd Order Indices					
Shelter and housing recovery needs	-.0355	-.1124	.0107	-.2352*	.1516
Civic capacity	.0375	-.1409	-.0335	-.5039*	.0391

** two-tailed p≤ 0.05.

The first three columns displaying the relationships between the SV measures and interviewer and respondent relative damage measures, shows only one statistically significant relationship. That is the relationship between the percent of a block group's housing that is mobile homes and the overall damage assessment by the interviewer (.2615). When examining the last column, which also reflects a relative damage measure, we again find only one statistically significant and positive correlation. That correlation (.2548) was between relative loss in home values and the percent non-white population in a block groups The significant positive correlation suggests that block groups with higher proportion of minorities suffered greater relative damage, which is consistent with SV expectations. On the whole then, rather than finding the significant and positive associations expected, there were only two significant correlations, one for percent mobile homes and the other for percent non-white populations. It should also be noted that there were no significant correlations for the 2nd and 3rd order composite SV measures.

While the findings with respect to relative loss were, with the exception of two correlations, not consistent with our expectations, those with respect to absolute loss were. The relationships between absolute loss (column 4) and many of the SV generally show the expected pattern in that blocks with higher levels of SV suffered lower amounts of absolute (dollar) damage. In some sense, these findings are not all that surprising. Higher concentrations of SV generally imply less affluent neighborhoods and housing, hence there is simply less value to lose in the first place.

Specifically we find significant and negative correlations between the absolute loss measure and elders in poverty, non-white population, housing units over 20 years old, housing unites without a phone, populations over 25 without a high school diploma, and low English competency. In addition, the overall composite SV index and 2nd order measures for housing needs and civic capacity needs all showed significant negative correlations.

On the whole then, the results are somewhat disappointing. With the exception of the two significant correlations associated with the relative loss measures and the consistent of significant negative correlations with respect to absolute loss, the results for Hurricane Ike suggest that the relationship between neighborhood SV and damage was not as consistent with the expectations of the literature. This finding may well suggest that, at least with respect to damage, SV analysis is of limited utility. However, this non-finding may also be a function of the unique characteristics of Ike and Galveston in general. More specifically, this result maybe a function of the particular nature of Ike – an extensive but gradual surge flooding event from its bayside with very limited wind damage and in nature of development on barrier islands, confounding the relationship physical vulnerability and real estate amenity.

Often times the literature finding a relationship between SV and relative damage is base on earthquake and wind related events in which poor quality housing, generally occupied by SV populations, are shaken apart or picked apart by winds. Furthermore, the work on floods generally is associated with inland communities where low-lying, flood prone areas have poor land values and more typically the sites for low-income housing and households. In the case of Ike however, we have an slow rising surge event impacting essentially all of the urban core, home to 85% of the island's inhabitants – both rich and poor, minority and majority, etc. – as well as housing of the relatively affluent on the west end with its outstanding view and proximity to a beach and bay. These latter homes may be at great physical risk, but their owners have very little social vulnerability, not only because these homes are often vacation homes and not primary residences, but more importantly because these households typically have very good access to resources—social, physical, and financial—to help them avoid lasting impacts from the storm. Thus, the nature of this event and Galveston's unique characteristics may well account for the lack of relationships between the SV measures and most damage measures. Another important factor is that this analysis is simply looking for the bivariate relationship between SV and relative damage, which is perhaps a more complex matter.

It is worth noting that more elaborate multivariate analysis conducted with the survey data and predicting the first relative measure of damage use in column one of table 7, does find the expected positive effect of various measures of social vulnerability. Specifically, Highfield, Peacock, and Van Zandt (2011), develop a multivariate model that sought to predict relative structural damage using a series of variable capturing a home's exposure to the flooding/surge hazard, the structures features, and its neighborhood's SV characteristics. The specific variables utilized to

capture these different sets of factors were as follows: a structures relative exposure to flooding/surge hazard was based on its distance from the water (bay or gulf), how close it was behind the Galveston's famous sea wall, its location in flood zones, and the actual water inundation level at a structure's location; the structure's features included how high it had been elevated and its age, as a proxy for building code quality; and finally social vulnerability measures included the percent Black and Hispanic population is the home's block group and how economically affluent the home's block group as assessed by the average home value. Not unexpectedly a home's hazard exposure and its structural features were statistically significant determinants of relative damage, working as one would have expected. Nevertheless, the social vulnerability characteristics were also statistically significant determinants as well, even after controlling for these other factors. Specifically, homes in progressively more Black and Hispanic neighborhoods (i.e., with higher percentages of these non-white populations) suffered disproportionally higher levels of relative damage and homes in more affluent neighborhoods suffered less relative damage. These findings suggest that SV is important, however given the complexities of the determinants of damage due to Ike's surge flooding, the simple bivariate relationship, reflected by a correlation coefficient, was obscured.

Recovery Resources: Given that damage was widespread and affected households in neighborhoods of all income levels and race/ethnicities, one might hope that recovery and recovery resources would also be fairly even and widespread. In this section, we explore the relationship between social vulnerability and recovery resources. While households may have access to a variety of resources for recovery after a disaster, insurance is perhaps the most commonly accessed. In addition to these private resources, additional public funds are poured into a community in the days and weeks after a disaster. In this analysis we will consider each category of resources separately.

Private recovery funds: First, we examine private recovery resources in the form of whether respondents had insurance (both owners and renters), as well as whether they had flood insurance, and, finally, whether they received a settlement. Again, as with other analyses, the individual household responses have been aggregated by computing the appropriate proportions or percentages within the block group that had various forms of insurance and received settlements. The general expectations are that neighborhoods with high SV would have lower access to these private resources and have fewer settlements.

Table 8 presents the correlation coefficients. The correlations with the composite social vulnerability index show strong negative associations with having had either home insurance or renters insurance. These correlations indicate that households in neighborhoods with generally high levels of overall social vulnerability are less likely to have either home owners or renter's insurance. While the signs for the correlations with flood insurance and having reached a settlement are negative, they are not statistically significant.

Table 8. Correlations between SV indicators and Insurance coverage/settlements

	Home Insurance	Flood Insurance	Renters Insurance	Received Settlement
SV Composite Index	-0.2720*	-0.1602	-0.3262*	-0.0990
1st Order of Base Indicators				
Percent Single parent households with children	.0390	-.1690	.0021	.0659
Percent population 65 or older	-.4202**	-.0512	-.1737	-.3368**
Percent Elders below poverty level	.0361	-.0891	.0486	-.0651
Percent occupied HUss without a vehicle	-.3270**	-.0727	-.3364**	-.1298
Percent pop. in renter occupied HUs	-.2045	.0868	-.3012**	.0550
Percent non-white population	-.2441**	-.2505**	-.3086**	-.0976
Housing units built 20 years ago	-.1358	-.1833	-.2778**	-.1454
Persons in poverty	-.0753	.0028	-.2219*	-.0027
Per. occupied HUs without a telephone	.0190	.0155	-.2216	-.0697
Per. pop. 25 or older w/o high school	-.3405**	-.2235**	-.3338**	-.2406**
Per. labor force unemployed	-.0262	.0151	-.2336**	-.0034
Percent ≥5 yrs. w/o English competency	-.3480**	-.1536	-.0034	-.1137
2nd Order Indices				
Shelter and housing recovery needs	-.2367**	-.1609	-.3493**	-.0490
Civic capacity needs	-.2772**	-.1526	-.3145**	-.1767*

Source: U.S. Census; HRRC survey; Coastal-planning atlas; * tail p≤.1; ** one-tail p≤.05.

A closer look at the base indicators suggests that neighborhoods with higher proportions of elderly, nonwhite, and low education households have a greater proportion of homeowners that are likely to be without home insurance. It may be useful to note that only homeowners with federally backed mortgages are required to carry home insurance; after homes are paid off, owners may opt to drop homeowner's insurance. For this reason, it is not surprising to see that neighborhoods with higher percentages of elderly, who are often on fixed incomes, have lower homeowners' insurance rates. Similar patterns are evident for rental insurance. By far the most disturbing finding, given the nature of this disaster, is the result for flood insurance. Neighborhoods with high proportions of minorities and those with higher proportions of adult individuals not completing high school have lower percentages with flood insurance. These findings suggest that these socially vulnerable neighborhoods in particular will be slower to recover because of a lack of private recovery resources.

The 2nd order SV indices for housing needs and civic capacity are also negatively associated with homeowner's and renter's insurance. Specifically, neighborhoods with higher shelter and housing recovery needs have lower rates of homeowners insurance and particularly renter's insurance, suggesting a disturbing lack of access

to this important resource for recovery capital. The SV measure for civic capacity needs is also highly negatively correlated with a lack of insurance. Since civic capacity includes potentially other types of nonfinancial resources, such as access to information and perhaps social support, this association could aggravate the lack of financial resources to slow or even prohibit recovery in these neighborhoods.

It is particularly significant to note that some areas of high SV are also reporting higher levels of failing to have an insurance settlement, which can significantly delay recovery and reconstruction for households with insurance in the first place. Specifically neighborhoods with high levels of elderly have lower proportions reporting insurance settlements. Additionally, neighborhoods with high levels of adults without a high school degree are also less likely to have received a settlement. This may be associated with greater difficulty filing claims or pursuing denied claims among this less-educated population. Regardless not having a settlement, will delay the recovery process. There is also a marginally significant, negative relationship between the 2nd order measure for civic capacity needs and having received an insurance settlement.

On the whole, the findings with respect to insurance and insurance settlements suggest that many vulnerable neighborhoods have lower access to these important sources of recovery funds, in part because of lower proportions that have insurance in the first place whether considering homeowners, renters, or most importantly, flood insurance. Furthermore, even among those that have insurance, settlements are reported at lower rates for high SV areas.

Public recovery funds: We next consider the availability and use of common public resources for recovery aid. There are a variety of forms of more "public" aid with FEMA and SBA as the most recognized. Assistance from FEMA generally comes in the form of grants for living expenses, housing assistance, and minimum home repairs to help families through emergency periods, displacement due to home damage, or to make emergency repairs to their homes. These funds are generally seen as minimal and limited, acting as a safety net for those without resources, either chronically or temporarily. Major assistance to homeowners to help rebuild or repair damage when private funds are not available comes in the form of low interest loans from the Small Business Administration (SBA). These are loans, however, and not grants; hence, they are awarded based on the likelihood that individual can repay the loan.

As part of the household survey, respondents were asked whether they applied for assistance from FEMA, SBA, or both and whether or not they had received any funding from either of these sources. Table 9 displays the correlations between the SV measures and the percentages of respondents within each neighborhood that applied for FEMA assistance, SBA low-interest loans, as well as whether any funds were received from either of these sources. While the literature suggests that there can be variations in household applications and receipt of IFG and SBA funding, the examinations of the general trends across neighborhoods suggests that, as intended,

FEMA grant programs go to areas with higher SV (minority and lower income areas) while SBA low interest loans funding tends to be in more affluent areas (Kamel and Loukaitou-Sideris 2004). In light of these findings, the expectations would be that higher levels of SV should be positively associated with applications to FEMA, while SBA applications should be negatively associated with SV indicators. Unfortunately, since the receipt of funding could be from either FEMA or SBA, the expectation is indeterminate and hence the findings will be considered more exploratory.

Table 9. Public Recovery Funds and Social Vulnerability Indicators.

	Apply to FEMA	Apply to SBA	Receive funding from either FEMA or SBA
SV Composite Index	.2718**	-.1817	.1538
Base Indicators			
Single parent households with children	.3016**	-.0636	.1826
Elders with age above 65	-.0231	-.2790**	-.0025
Elders with age above 65 are below poverty level	.0860	-.1744	.2217*
Occupied housing units without a vehicle	.2901**	-.2828**	.2116*
Persons in renter occupied housing units	.2341*	.0013	.1958
Race/ethnicity (non-white population)	.1827	-.0567	.0420
Housing units built 20 years ago	.0754	-.2542**	-.0996*
Persons in poverty	.2417*	-.2255*	.1845
Occupied housing units without a telephone	.2393**	-.0884	.0013
Educational attainment less than high school	.0363	-.1184	.1345
Labor force unemployed for age above 16	.2949**	-.1441	.0507
Speak English not well or not at all	-.0137	-.0445	-.0126
2nd Order Indices			
Shelter and housing recovery needs	.2694**	-.1186	.1190
Civic capacity	.1677	-.1444	.0908

Source: U.S. Census; HRRC survey; **two-tailed p≤ 0.05; * two tailed p ≤0.10

The findings are generally consistent with the expectations in that neighborhoods with higher SV indicators also had higher proportions reporting applying for FEMA assistance, yet lower proportions applying for SBA loans In terms of the general composite SV measure, we find that households in more socially vulnerable neighborhoods, are more likely to apply for FEMA assistance. Similarly, neighborhoods with higher proportions of single parent households, households without a car, renters, living in poverty, homes without phones, and unemployed apply to FEMA only. The 2nd order index, reflecting higher proportions likely to be in need of shelter and housing recovery assistance also was positively associated with higher levels of FEMA applications. It should however be noted that FEMA aid is not designed for, nor is it sufficient to undertake anything more than minimal emergency repairs to a home.

On the other hand, the relationship between socially vulnerable households and applying for SBA loans is negative, despite what we have already seen as low access to homeowner and flood insurance, indicating that higher concentrations of socially vulnerable households have relatively lower applications to these sources. More specifically, significant negative correlations are found for areas with high proportions of individuals living in poverty, older homes, or homes without vehicles, as well as combinations of elderly or elderly living in poverty. Again, these findings are not too surprising because applications for an SBA low-interest loan suggests the ability to repay that loan, which will be much more difficult in poorer areas and for older individuals who are reluctant to incur higher levels of debt at their age or financial status.

Interestingly, only areas with higher proportions of poor elderly and households without cars show relatively higher proportions that received some form of aid from these sources, although the correlations are only marginally significant. While it is impossible, given the nature of the information collected, to be clear which form of assistance was received; one might deduce given the nature of high SV areas that this is more likely to be aid in the form of grants from FEMA and not SBA loans. To the extent that this is the case, these findings in conjunction with the negative relationships between these two SV indicators and insurance, suggest that more public sources are indeed filtering into areas that are lacking recovery resources from insurance. However, only a very small slice of SV neighborhoods appear to be actually receiving such assistance at rates greater than the rest of socially vulnerable neighborhoods.

Public resources for recovery are expected to be a safety net for households who do not have any or adequate private resources (primarily insurance and savings) for recovery. It should also be noted that this safety net is minimal and not designed to replace funding from private sources nor is it designed to repair homes. Minimal home repair is just that, designed to put a tarp on a damaged roof, not replace the roof, until other funding is available. They are income-qualified programs that should be targeted to those households most in need of such assistance. This is clearly the public perception of these programs, which explains the moderately strong relationships with application rates for FEMA assistance and negative relationships with SBA applications in highly vulnerable areas. That we do not see higher positive relationship for receipt for a broader spectrum of socially vulnerable areas suggests that these programs may have gaps in their ability to target at-risk neighborhoods.

Recovery: Recovery is signified by building activity—home owners, business owners, and residents undertaking repairs to their damaged homes or businesses, or rebuilding on their lots after homes have been destroyed. In Table 10, we examine the relationship between social vulnerability and indicators of early recovery activities. Specifically, we look at the proportion of households in neighborhoods that have undertaken significant repairs, as reported in our household survey conducted several months after the hurricane, as well as the

percent of housing units in the neighborhood that have not yet received permits for reconstruction, and the average number of months before the first permit was granted for each neighborhood. These latter indicators were created using data from the City of Galveston's building permit system. The overall SV expectations are that neighborhoods with high SV levels should be negatively associated with the proportion of significant repairs started in the area, positively associated with higher proportion of properties not having permits to start major rebuilding and repair efforts and positively associated with the average number of months before the first single family permit issues for major repairs or rebuilding indicating greater delays in recovery efforts.

Table 10. Housing recovery indicators and Social Vulnerability Indicators

	Undertaken Significant Repairs	Percent not having received permits	Average months to first permit
SV Composite Index	-.1854**	.2718**	.2063**
Base Indicators			
Single parent households with children	-.0798	.0331	-.0365
Percent population 65 or older	.1741	.0469	.1657*
Percent Elders below poverty level	-.0644	.1630*	.0706
Occupied housing units without a vehicle	.0005	.1137	.1174
Percent population in renter occupied HUs	-.0780	-.0026	.0809
Percent non-white population	-.2442**	.3353**	.2072**
Housing units built 20 years ago	-.2851**	.4937**	.2947**
Persons in poverty	.1274	.0569	.0024
Per. occupied HUs without a telephone	-.1708*	.1529	.1302
Per. pop. 25 or older w/o high school	-.2841**	.4199**	.3894**
Per. labor force unemployed for age above 16	.0124	.1503	.0418
Percent ≥5 yrs. w/o English competency	-.1692*	.1379	.1545
2nd Order Indices			
Shelter and housing recovery needs	-.2154**	.2695**	.1801*
Civic capacity	-.2327**	.3533**	.2990**

Source: U.S. Census; HRRC, City of Galveston building permits, and Coastal Planning Atlas; **two-tailed p≤ 0.05; * two tailed p ≤0.10

Beginning first with measures from the survey data found in the first column, we see that there is a marginally significant negative correlation between sampled households reporting starting significant repairs and the composite SV index suggesting that highly vulnerable neighborhoods show lower rates of undertaking significant repairs. Furthermore, and more importantly, there are a number of highly significant relationships with the 1st and 2nd order measures. Specifically, neighborhoods with higher proportions of minorities, neighborhoods with older housing stock, and those with lower adult educational attainment are less likely to have begun undertaking significant repairs. While only marginally significant, we also see that neighborhoods with higher percentages of individuals not speaking English well display lower levels undertaken significant repairs. Also as anticipated,

neighborhoods with higher shelter and housing recovery needs and those with higher civic capacities needs are less likely to have begun significant repairs.

Interestingly, when employing permitting data that canvases all block group structures and not just relatively small sample of single family home within neighborhoods, the general pattern is replicated and in some cases appears stronger. Starting with the results in column 2, for the proportion of structures within a neighborhood that have not been permitted for repairs, we see a fairly strong and significant association with the composite social vulnerability index. The same base indicators—nonwhite population, low education levels, older housing stock, and while only marginally significant, areas with higher percentages of elders living in poverty are positively associated with larger percentages not having received permits. With respect to the 2nd order SV measures, we also see that those areas with high shelter and housing recovery needs and high civic capacity needs have larger proportions of structures that have not obtained permits to begin rebuilding or repairing homes. These findings are all consistent with the SV expectations.

In the third column, we look at average time to first permit—a variable which indicates how quickly households were able to begin undertaking repairs and rebuilding. We see that the overall social vulnerability index is positively associated with the number of months before the first permit was applied for suggesting that socially vulnerable neighborhoods are taking significantly longer on average to even begin repairs and rebuilding. The correlations with the base indicators suggest that areas with higher percentages of non-Whites, older housing, and populations with low levels of education are all later, on average, before the first permits are being pulled for rebuilding and repair work. With respect to the 2nd order SV measures, we find that areas with high civic capacity needs and, all be it marginally significant, areas with high housing needs were also later, on average, in pulling initial permits for rebuilding/reconstruction efforts.

The findings with respect to the early stages of recovery clearly suggest that more vulnerable neighborhoods – those that are older and those that are composed of greater percentages of minorities and those with higher percentages of adults without a high school degree – are certainly rebuilding and recovering at a slower pace. The literature suggests that they may well be less likely to ever recover. In some cases, these neighborhoods may become targets for redevelopment—meaning the properties are demolished and replaced with different uses— for higher-income housing or nonresidential uses, for example (Yang and Peacock 2010). In cases like this, communities may see an overall loss of affordable housing, and may displace original residents, perhaps permanently.

Summary: The overall conclusions from examining the utility of the *Coastal Planning Atlas's* strategy for measuring and mapping socially vulnerable block groups (neighborhoods), at least with respect to Galveston's Hurricane Ike experience has been, on the whole, positive. The use of 1st, 2nd, and 3rd order SV measures was show to be of utility when assessing response to warning, in the

sense of evacuation rates and timing, when assessing access to recovery resources including various forms of insurance and public resources, and finally, and most importantly, when assessing various forms early recovery and rebuilding. The one area that was less than satisfactory was in the area of flooding damage due to Ike, where there were only a few indicators that appears to work in identifying relative losses as opposed to absolute losses. However, neighborhood SV measures did perform as expected in more complex multivariate analysis predicting relative losses. On the whole, the use of the Atlas's SV strategy and mapping tools can be utilized by coastal community planners and emergency managers to effectively identify areas within their own communities which, due to their social vulnerability characteristics, are going to have lower levels, capacities and abilities to, in the words of Blakie et al (1994:9), "anticipate, cope with, resist and recover from the impacts of a natural hazards." It therefore is incumbent, particularly given the status and trends toward greater levels of social vulnerability within the Texas coastal management zone, for planners and emergency managers to utilize such tools to address this issue of growing concern.

VII. Comprehensive Disaster Mitigation and Recovery Planning for Resilience.

Resilience implies the ability to resist or absorb impacts and rapidly bounce back from those impacts. In the case of natural disasters and social systems, this implies the ability and capacity to prepare, respond, withstand the disaster impacts without major damage, and most importantly, to bounce back from the impact sustained. But when addressing communities, the picture is often far more complex because communities are composed of networks of businesses, governmental organizations, and most importantly, households and families living in areas that make up a complex mosaic of socially-defined neighborhoods. These neighborhoods are not the same, nor are they equal opportunity venues. They can be as different as night and day in terms of their socio-economic composition, the quality and types of housing, and their access and ability to mobilize resources when "bad" things happen. In a very real sense, social vulnerability mapping reveals disparities that make a difference when it comes to the capacity of residents and households to respond, mobilize resources, and bounce back from natural or other types of disasters.

This report has discussed one research-based approach that identifies those social, economic, and cultural factors that have been seen to be relevant to decision-making and behavior in responses to disaster. Furthermore, we have utilized census data at the lowest level of aggregation that still provides a wealth of information related to vulnerability, but does so at a unit of aggregation likely to be more parsimonious with neighborhoods: census block groups. These units also have an advantage is that they are workable in the context of planning policies, actions and programs. In other words, community planners, emergency management personnel, and civic leaders can utilize such information to identify neighborhoods where they can work with local civic organizations, target education programs, locate

emergency shelters, and coordinate evacuation pick-ups, etc. to better meet the needs of these populations.

The approach presented does appear as an effective method of identifying target areas likely to experience particular problems when addressing hazard risk and disaster response, impacts and recovery. Comparing needs predicted by the Coastal Atlas to actual needs expressed after Hurricane Ike, this tool did indeed identify neighborhoods that failed to heed or were slower to respond to calls for evacuation, that had lower levels of private and public resources, particularly resources necessary for rebuilding, repairs, and ultimately recovery. And finally, this approach identified neighborhoods that were on the slow track to recovery and at jeopardy of failing in that pursuit. These failures have consequences not only for the households in those areas, but for the community as a whole, because these become areas at risk of cycling down to become pockets of economic and social despair that can threaten the overall resilience of the community, particularly if they spread.

In short, indicators of social vulnerability did make a difference. The neighborhood disparities identified by SV mapping did identify neighborhoods that were quite different in their abilities to respond to Hurricane Ike and bounce back from its impacts. This suggests that using social vulnerability mapping in conjunction with hazard map and physical vulnerability mapping can greatly facilitate community planning for disaster response, recovery, and mitigation. With this approach we can better plan for and monitor our community vulnerabilities and thereby develop more comprehensive planning approaches that can enhance long term community resiliency. Furthermore, in light of the current status and trends with respect to social vulnerability, it is critical that we employ social vulnerability analysis as a critical element in community and hazard planning.

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