Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina

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Losses from environmental hazards have escalated in the past decade, prompting a reorientation of emergency management systems away from simple postevent response. There is a noticeable change in policy, with more emphasis on loss reduction through mitigation, preparedness, and recovery programs. Effective mitigation of losses from hazards requires hazard identification, an assessment of all the hazards likely to affect a given place, and risk-reduction measures that are compatible across a multitude of hazards. The degree to which populations are vulnerable to hazards, however, is not solely dependent upon proximity to the source of the threat or the physical nature of the hazard—social factors also play a significant role in determining vulnerability. This paper presents a method for assessing vulnerability in spatial terms using both biophysical and social indicators. A geographic information system was utilized to establish areas of vulnerability based upon twelve environmental threats and eight social characteristics for our study area, Georgetown County, South Carolina. Our results suggest that the most biophysically vulnerable places do not always spatially intersect with the most vulnerable populations. This is an important finding because it reflects the likely "social costs" of hazards on the region. While economic losses might be large in areas of high biophysical risk, the resident population also may have greater safety nets (insurance, additional financial resources) to absorb and recover from the loss quickly. Conversely, it would take only a moderate hazard event to disrupt the well-being of the majority of county residents (who are more socially vulnerable, but perhaps do not reside in the highest areas of biophysical risks) and retard their longer-term recovery from disasters. This paper advances our theoretical and conceptual understanding of the spatial dimensions of vulnerability. It further highlights the merger of conceptualizations of human environment relationships with geographical techniques in understanding contemporary public policy issues. *Key Words: hazards, vulnerability, geographic information systems, risk.*

A profound change in governmental disaster management has occurred during the last two decades. Gone are the days of "hunkering down" and riding out the hazard event with a command and control mentality that only focused on clean-up and the rescue of survivors. In its place is an emphasis on the reduction of loss of life and property through mitigation, preparedness, response, and recovery. The impetus for change was spurred largely by the costly disasters of the last decade: the Loma Prieta earthquake and Hurricane Hugo (1989), Hurricane Andrew (1992), the Midwest floods (1993 and 1995), the Northridge earthquake (1994), and most recently, Hurricane Floyd (1999). Pressed by Congress, the Federal Emergency Management Agency (FEMA) reprioritized its mission toward reducing future hazard impacts by implementing the National Mitigation Strategy (FEMA 1995).

One core element of the National Mitigation Strategy is hazard identification and risk assessment. A guiding principle behind this element is that risk-reduction measures for one hazard should be compatible with risk-reduction measures for other hazards. This eliminates the possible substitution of one risk for another, such as relocating people from a floodplain to higher

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ground, which turns out to be a landslide-prone hillside. Mitigating against the effects of potential disasters and having the appropriate infrastructure in place for response requires detailed knowledge on the vulnerability of the places to a wide range of environmental hazards. To assist in developing such an "all hazards" assessment, the Federal Emergency Management Agency (FEMA) and the National Emergency Management Association (NEMA) unveiled a State Capability Assessment for Readiness, which provides an objective way to gauge hazard mitigation and preparedness (FEMA and NEMA 1997). This publication was supplemented with a primer on hazard identification and assessment at the state level only (FEMA 1997). While laudatory in scope, the FEMA guidelines defined hazard vulnerability as the mere presence or absence of a source of risk such as earthquake faults, coastal areas, or rivers.

The degree to which populations are vulnerable to hazards is not solely dependent on proximity to the potential source of the threat. Social factors such as wealth and housing characteristics can contribute to greater vulnerability on the part of some population subgroups. As White and Haas (1975: 8) noted almost 25 years ago, the following factors contribute to the nation's vulnerability to hazards:

1. Population shifts from rural to urban to suburban and exurban result in more people living in seismic risk areas, unregulated floodplains, and exposed coastal locations;
2. Increased mobility means that more people live in new surroundings and are unfamiliar with the risks in their area and how to respond to them;
3. Economies of scale in industries result in plants being located in high-risk areas, since industry can often absorb the costs. When the plants locate in hazardous areas, so do employees and their families, thus increasing vulnerability;
4. The increase in new housing starts from manufactured housing (mobile homes) means that more people are living in dwellings that are likely to be damaged by natural hazards.

These factors are just as germane now as they were in the 1970s. More important, the density of infrastructure, the sheer number of people living in riskier areas, and the increasing disparities in wealth and socioeconomic status increase the potential for greater human losses to hazards in the future (Mileti 1999). Yet a discussion on the role of social indicators in enhancing or reducing vulnerability is nonexistent in the FEMA guidance.

This paper uses a conceptual model of vulnerability that incorporates both biophysical and social indicators to provide an all-hazards assessment of vulnerability at the local level. The descriptive approach is designed to aid in our understanding of the complexities of vulnerability and to see how it plays out in a real-world setting. We selected the county scale and used subcounty social and hazard indicators as much as possible. The selection of Georgetown County, South Carolina as our study site was driven by three considerations. First, the research team has extensive experience and knowledge of the area. Second, the county has a vast array of different types of hazards and a broad sociodemographic profile. Finally, our ability to construct and enhance the contextual nature of the data is facilitated by this geographic scale of analysis.

Rediscovering Geography as Human Ecology

The initial birth of hazards research in geography is attributed to Harlan Barrows and his presentation of "geography as human ecology" (Barrows 1923). Employing the human ecological approach, Barrows and his students delved into the study of how people and society adjust to environmental extremes, most notably floods (Kates and Burton 1986). The research was driven not only by intellectual curiosity, but also by a desire to solve a practical problem. Gilbert White's work (1945, 1964), in particular, was significant in rethinking and reshaping national flood-management policy. Decades later, another geographer, Gerry Galloway, had a similar impact on national flood policy following the disastrous 1993 Midwest floods (Interagency Floodplain Management Review Committee 1994).

White and his students (first at the University of Chicago and later at the University of Colorado) formed the core of natural-hazards researchers well into the 1970s. This ensemble of researchers focused on (1) the identification and distribution of hazards, (2) the range of adjustments that are available to individuals and society, and (3) how people perceive and make choices regarding hazard events. The culmination of much of this research was presented in *The Environment as Hazard* (Burton et al. 1978). The traditional natural-hazards approach soon evolved into a pragmatic geographic response to broader societal issues.

The historic emphasis in hazards research on solving practical problems produced a number of critiques among the research community during subsequent decades, which expounded on the lack or narrowness of theory underpinning hazards research (Hewitt 1983, 1997; Watts 1983; Oliver-Smith 1986; Alexander 1991, 1997; Lindell et al. 1997). In addition to the narrowness of the theory and the singular focus on extreme natural events, criticisms included a lack of international research sources, an ignorance of the anthropological literature on human-environment relations (Torry 1979), and the more contemporary view that natural hazards are socially and culturally constructed (O'Keefe et al. 1976; Douglas and Wildavsky 1982; Susman et al. 1983; Johnson and Covello 1989; Krimsky and Golding 1992; Blaikie et al. 1994; Palm and Carroll 1998).

Although extreme natural events have long been the primary research focus, the recognition that hazards are not just physical events, but also include socially constructed situations, has broadened both the definition of hazard and geographers' approaches toward understanding and ameliorating them. Technological failures and risk management received considerable attention by geographers (Kates et al. 1985; Sorenson et al. 1987; Cutter 1993; Mitchell 1998). The extensive occurrence of these types of hazards and their rising attention level among the public and decisionmakers are driving this current research focus much like the pragmatic concerns of the Cold War era defined disaster research from 1950-1980 (Quarantelli 1988). Indeed, the distinction between natural and technological hazards is now blurred, with hazards viewed as a continuum of interactions among physical, social, and technological systems. In fact, global environmental change and awareness of technological hazards caused by natural events contributed to this reconceptualization.

Acknowledging the critiques of the natural hazards paradigm, especially from the political economy perspective, hazards research now considers not only the hazards themselves, but the particular contexts in which they are embedded. This context includes the geography of the event and the physical properties of the hazards (physical geography), as well as aspects of the social, political, spatial, temporal, organizational, and economic milieu within which the hazard takes place. One approach, *hazards in context*, is best embodied in the work of Mitchell et al. (1989) and Palm (1990). This research methodology uses both empirical and social analyses and recognizes that hazards are inherently complex physical and social phenomena. Geographic scale is a central component in this perspective.

Another approach is derived from the risk research community. In their pioneering work, Kasperson et al. (1988) suggest that risks (the term hazards easily could be substituted) interact with cultural, social, and institutional processes in such a way as to either temper public response or heighten it. This *social amplification of risk* model helps us to interpret public perceptions and, ultimately, policy responses to risk and hazards in contemporary society.

A third perspective examines vulnerability—its causal structure, spatial variability, and methods for reduction. Broadly defined, vulnerability is the potential for loss of property or life from environmental hazards, although there are many competing and contradictory definitions of the concept, as pointed out elsewhere (Cutter 1996). Individual vulnerability, for example, refers to a specific individual or structure and is most often examined by the health and engineering sciences respectively. Social and biophysical vulnerability are broader in scope and refer to social groups and landscapes that have the potential for loss from environmental hazards events. Most of the hazards literature examines vulnerability as a preexisting condition (e.g., potential exposure), largely describing the biophysical forces that produce risks and hazards (Cutter and Tiefenbacher 1991; Burton et al. 1993). The geographical manifestation of this perspective is a locationally dependent analysis based on proximity to the source of the threat. Other research suggests, however, that the causal structure of vulnerability may be dependent upon the underlying social conditions that are often temporally and geographically remote from the initiating hazard event. The term *social vulnerability* is used to define the susceptibility of social groups to potential losses from hazard events or society's resistance and resilience to hazards (Blaikie et al. 1994; Hewitt 1997). The nature of the hazard event itself is usually taken as a given, for this research normally highlights the historical, cultural, social, and political processes that give rise to "unsafe" conditions in the first place. Most of the social-vulnerability literature examines slow onset or chronic types of hazards, such as industrial pollution (Yarnal 1994), global environmental change (Dow 1992), or drought and famine (Bohle et al. 1994).

While the notion of vulnerability as potential exposure or social resilience is most prevalent in the literature, the integration of the two is occurring with a more pronounced focus on specific places or locations. The concepts of vulnerability and multiple hazards in a place (*hazard of place*) encompass both biophysical and social vulnerability, and are applied to many geographic domains ranging from the local to the global. Examples of the integration of biophysical and social vulnerability in understanding hazards and societal responses to them can be found in studies on the causes and consequences of land degradation (Blaikie and Brookfield 1987), drought (Wilhite and Easterling 1987; Liverman 1990a, 1990b), and severe environmental degradation in selected world regions (Kasperson et al. 1995).

The interplay of social, political, and economic factors—interacting separately, in combination with one another, and with the physical environment—creates a mosaic of risks and hazards that affect people and the places they inhabit (*riskscapes* or *hazardscapes*). Cutter and Solecki (1989) proposed the hazards-of-place concept to examine the distributive patterns of hazards and the underlying processes that give rise to them. The study of the hazards of place has its roots in Hewitt and Burton's (1971) regional ecology of damaging events. They maintain that considering the threat from all hazards provides an opportunity to mitigate several hazards simultaneously. Yet previous work has rarely attempted to characterize the risk from all hazards or the intersection they share with vulnerable populations. A notable exception is FEMA's (1997) publication, *Multi Hazard Identification and Risk Assessment*. Curiously, however, this report provides a hazard-by-hazard analysis (at the state level), including natural and technological hazards, but there is no overall summary of cumulative hazards within the states, so it is impossible to ascertain the relative hazardousness of states. There is also no mention of the social vulnerability of residents living in these places.

In this paper, we further extend this research methodology by incorporating biophysical and social indicators with location for all hazards in a particular area, in this instance, a county. In this way, we extend some of the theoretical, conceptual, and technological advancements in hazards research to a real-world application, including the use of GIS in hazard mapping (Monmonier 1997).

Conceptual Model and Practical Implementation

To organize and combine both the traditional view of vulnerability (biophysical risk) with the more recent ideas on social vulnerability, Cutter (1996) developed a hazards-of-place model of vulnerability (Figure 1). While exploratory in nature, it seeks to integrate the two aspects of vulnerability by tying them both to particular places. The focus on place provides an opportunity to examine some of the underlying social and biophysical elements that contribute to vulnerability, as well as to assess their interaction and intersection. Place vulnerability can change over time based on alterations in risk, mitigation, and the variable contexts within which hazards occur.

Risk and mitigation interact to create an initial hazard potential. Risk is the likelihood of the event occurring and includes three subele-

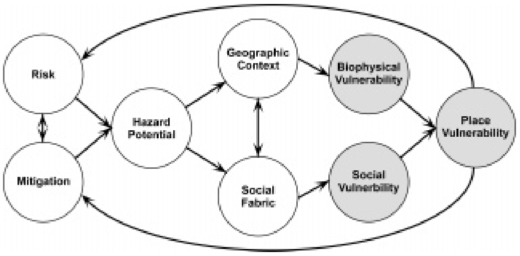

Figure 1. The hazards-of-place model of vulnerability (Cutter 1996). Risk and mitigation interact to produce the hazard potential, which is filtered through (1) the social fabric to create social vulnerability and (2) the geographic context to produce biophysical vulnerability. The interaction between biophysical and social vulnerability creates the place-vulnerability. Note the interactions and feedback loops throughout the model.

ments: the potential source of the risk (e.g., industrial accident, riverine flooding), the impact of the risk itself (high-consequence, low-consequence event), and an estimate of its frequency of occurrence (500-yr flood, 2 percent chance of a valve failure). Risk interacts with mitigation (a whole suite of efforts to reduce risks or lessen their impacts such as planning or structural improvements in buildings) to produce the hazard potential. Following from the social amplification model, risks can either be reduced through good mitigation policy, or amplified by poor or nonexistent mitigation policies and practices. The hazard potential interacts with the underlying social fabric of the place to create the social vulnerability. The social fabric includes sociodemographic characteristics, perception of and experience with risks and hazards, and overall capacity to respond to hazards. The geographic filter includes the site and situation of the place and the proximity to hazard sources and events, and interacts with the hazard potential to produce the biophysical vulnerability. The social and biophysical vulnerability elements mutually relate and produce the overall vulnerability of the place. Notice that the place vulnerability has a feedback loop to the initial risk and mitigation inputs, allowing for the enhancement or reduction of both risk and mitigation, which in turn would lead to increased or decreased vulnerability. To operationalize the conceptual model, we focused only on the last three elements: biophysical, social, and place vulnerability. Three outcome indicators were used to measure the relative hazardousness of Georgetown County: biophysical vulnerability (measured by event frequency and delineation of hazard zones), social (measured by sociodemographic characteristics), and overall place vulnerability (the interchange of the two).

A key component of any vulnerability assessment is the acquisition of systematic baseline data, particularly at the local level. These data provide inventories of hazard areas and vulnerable populations—information that is essential for preimpact planning, damage assessments, and postdisaster response. One ancillary goal of this research is to create a method for identifying the risk posed by multiple hazards in order to promote mitigation at the local level. A vulnerability assessment requires not only an audit of all potential hazards, but also an understanding of the human dimensions involved.

The fundamental causes of human vulnerability include a lack of access to resources, information, and knowledge, and limited access to political power and representation (Blaikie et al. 1994; Institution of Civil Engineers 1995). Certain demographic factors are prominent when establishing social vulnerability. Age is an important consideration in evacuations, specifically the elderly and young who are more difficult to move and subject to health complications from certain hazard events (McMaster 1988; O'Brien and Mileti 1992). The poor are more susceptible to certain hazards due to lack of resources, poor-quality housing, and the inability to recover quickly (Burton et al. 1993; Dasgupta 1995). Conversely, the richest households may experience greater material losses during a hazard event, but that same wealth also enables them to absorb those losses through insurance, social safety nets, and entitlements, and thus, to more quickly recover from the hazard's impact. Gender can also be an indicator of a more vulnerable population due to a lack of access to resources and differential exposures (Liverman 1990a; Cutter 1995; Fothergill 1996; Enarson and Morrow 1998). The environmental equity literature also supports race and ethnicity as factors in vulnerability to certain hazards (Perry and Lindell 1991; Pulido 2000; USGAO 1995). Finally, population distribution and density further serve as vulnerability indicators, since higher concentrations of people present further evacuation difficulties (Johnson and Zeigler 1986; McMaster 1988; Cova and Church 1997).

Place vulnerability, while largely shaped by biophysical and social factors, is also compounded by a population's reliance on infrastructure that includes roads, utilities, bridges, dams, airfields, railroads, and emergency response facilities. According to Platt, many of these infrastructure components fall under the definition of "lifeline," the networks that "provide for the circulation of people, goods, services, and information upon which health, safety, comfort, and economic activity depend" (1995: 173). "Special needs" locations or populations also exist that require careful consideration for hazard and emergency response due to the requirement for advanced evacuation lead time and the difficulty in relocation. Examples of special needs facilities include daycare centers, nursing homes, hospitals, and schools.

The use of Geographic Information Systems (GIS) is growing in emergency planning and management, and FEMA recently embraced the technology, especially for monitoring responses and estimating losses (Marcello 1995; FEMA 1997). Within the research community, GIS-related studies have been used in hazard identification (Chou 1992; Wadge et al. 1993; Jones 1995; Brainard et al. 1996; Carrara and Guzzetti 1996) and in social response (Hodgson and Palm 1992; Sorenson et al. 1992). Relatively few researchers have used GIS as a tool for understanding both biophysical *and* social vulnerability. There are some notable exceptions, including the work of Emani et al. (1993), who investigated vulnerability to extreme storm events and sea-level rise, and the work of Lowry et al. (1995), who examined vulnerability to hazardous chemicals releases. Clearly, there is a void in the literature on the spatial analytic approach to vulnerability, a shortcoming that this present paper addresses.

Georgetown County, South Carolina

Georgetown County is located along the South Carolina coast between Myrtle Beach, a high-volume tourist destination to the north, and the historic city of Charleston to the south (Figure 2). The county is diverse in both its physical landscape and social structure. The

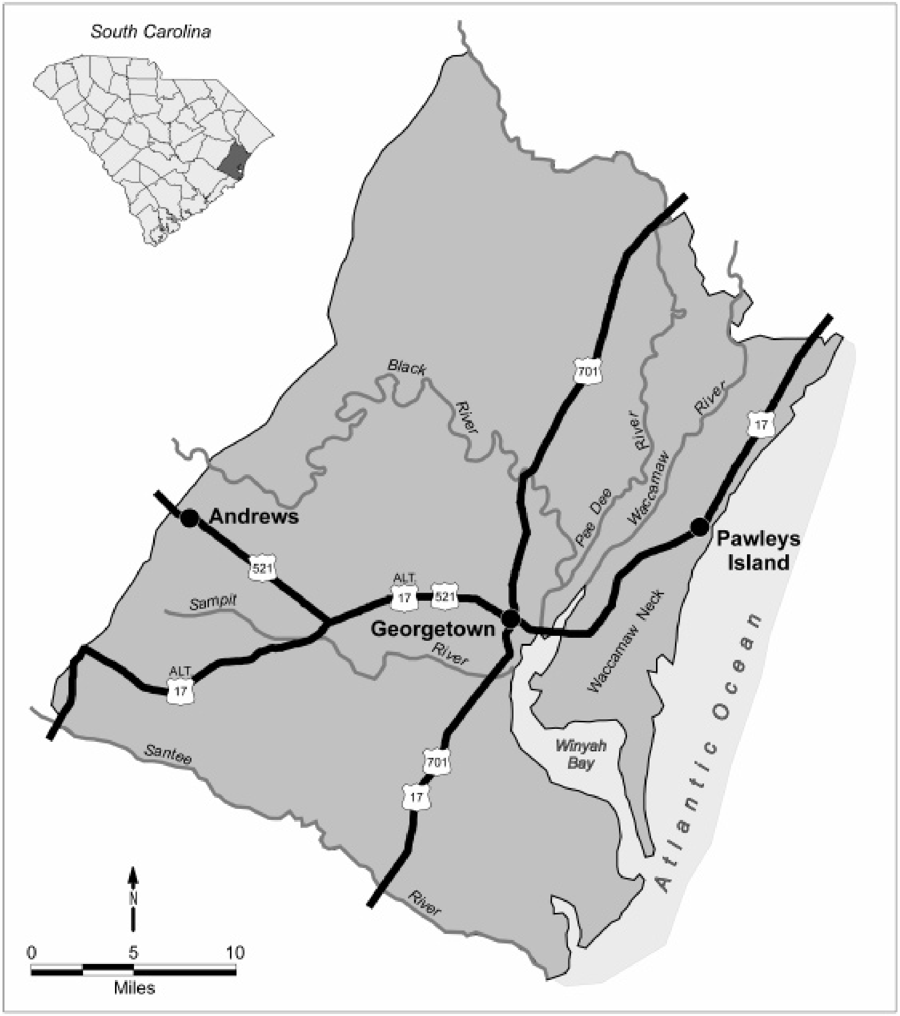

Figure 2. Georgetown County, South Carolina.

Sampit, Black, Great Pee Dee, and Waccamaw Rivers converge upon the city of Georgetown and empty into Winyah Bay. The southern border of the county is formed by the Santee River. This low-lying, poor-draining area contrasts with the quasi-barrier island landscape of the so-called Waccamaw Neck region, which is separated from the mainland by the Waccamaw River and the Intracoastal Waterway and is accessible by bridge from Georgetown.

The county is about 815 square miles (eighth largest in the state). Its population density (63.3 persons per square mile) is lower than the state average but ranks in the middle of all South Carolina counties. More than 60 percent of the county's tax base is derived from the Waccamaw Neck beachfront communities of Murrells Inlet, Pawleys Island, Litchfield Beach, and Debordieu Colony (Cutter et al. 1997). Pawleys Island and Debordieu are among the state's more elite beach enclaves (Edgar 1998). The county seat, Georgetown, was one of the earliest port cities in South Carolina. Agriculture, especially the cultivation of indigo and rice, dominated the colonial and antebellum economy. During the 1840s, nearly half of the rice produced in the U.S. was grown in Georgetown County (Rogers 1970). Traces of the rice plantations and the tenant housing for the slaves that worked them are still visible in the landscape.

Today, the county has a diverse economic base, with two of the state's largest manufacturers, Georgetown Steel and International Paper, located in the city itself. The paper and pulp industry also owns 28 percent of the county's forested land. Tourism doubles the population during the summer months and generates more than $115 million in annual sales (Waccamaw Regional Planning and Development Council 1997).

The county is stratified both racially and economically. In the county as a whole, the percentage of minority population is 44 percent, compared to the state average of 31 percent. Per capita income is lower than the state average. The percentage of families living in poverty (15.8 percent) exceeds the state average as well (11.9 percent) (South Carolina Budget and Control Board 1997). Mean housing values are greatest along the coast, where most residents are white. As one travels inland, the housing value drops and the population becomes more racially mixed, especially in the city of Georgetown. In the rural areas, the population is predominantly black and poor. The majority of housing is single-family detached houses. Due to increased housing demand, land costs, and construction costs, one-fourth of the county's housing stock now consists of mobile homes. Finally, the cultural diversity of the county ranges from a year-round tourist-based population to one of the few remaining Gullah communities (Sandy Island) along the southeast coast[1] (Winberry 1996).

Georgetown County historically has been exposed to several recurring types of natural hazards. Primarily meteorological and hydrometeorological in nature, these include hurricanes, tornadoes, hail, floods, severe thunderstorms, and wind events. Forty-six deaths have been attributed to natural events, forty-one before 1900 and five in one incident in 1974 (Cutter et al. 1997). The majority of damage caused by natural hazards at the turn of the century were crop losses. Although the amount of rice grown in the county decreased after the Civil War, rice remained the primary agricultural commodity until the early 1900s. As a consequence of both the hazards that occurred (hurricanes) and the physical location of the fields (coastal riverine), rice-crop failures were commonplace. Crop losses have varied from a 25-percent loss in 1893 to a 90-percent loss in 1928, both due to hurricanes (Rogers 1970).

The shift from an agricultural to an industrial and tourism-oriented economy, beginning in the 1950s, fundamentally changed the nature of Georgetown County's exposure to hazards. Where a hurricane once washed out a rice field, it now has the potential to wipe out vacation condominiums (Schneider 1995) or spur the release of hazardous chemicals from an industrial facility. The transportation of chemicals used in manufacturing and the hazardous wastes generated at similar facilities have added to the hazard mosaic of the county.

Determining Biophysical Vulnerability

The identification of potential hazards, their frequency, and their locational impacts are essential components in describing biophysical vulnerability. The hazards we analyzed represent more acute events (e.g., hazmat [hazardous materials] spills, hurricanes)—situations that local emergency managers must respond to during an emergency situation—rather than the entire array of hazards that potentially affect areas (e.g., pollution). Three sets of information were required for the analysis: identification of hazards, hazard frequency, and hazard-zone delineation.

Hazard Identification and Frequency

The first step was to determine what hazard events occurred in the study area (Kates and Kasperson 1983; National Research Council 1991; FEMA 1997) and the estimated rate of occurrence based on the historical frequency of hazard events. The hazard history of the county was compiled from archival materials (especially the local newspaper, the *Georgetown Times*, which began publishing in 1798), and existing longitudinal hazards databases.[2]

The frequency of occurrence is a straightforward calculation from the historical data and the length of that record in years. The number of hazard occurrences divided by the number of years in the record yields the rate of the event occurring in any given year. For instance, if a hypothetical hazard, A, occurred 17 times in the county over the past 23 years, the rate of occurrence for that hazard in any given year is 17/23 (or .739), or less than once per year.

Table 1 provides the hazard frequencies for each of the primary hazards affecting Georgetown County, as well as the source of the data. While emergency-preparedness officials are most concerned with hurricanes, it is clear that wildfires and chemical releases from stationary facilities are the more common hazard events in the county.

In some instances, the calculation of an occurrence rate required more detail than the number of events per some unit of time. For example, drought hazard occurrence was calculated using data from the Palmer Drought Severity Index (PDSI). The PDSI is calculated from the weighted differences between actual precipitation and evapotranspiration (Palmer 1965), with a scale typically ranging from +4.0 (very moist spell) to zero (near normal) to −4 (extreme drought). Data for Georgetown County were acquired from the Southeast Regional Climate Center. We defined a drought year as being any year in which the PDSI exceeded the moderate drought level of −2.0 for any three consecutive months. Unfortunately, since a true definition of drought should include both physical and human systems, this method still is deficient in assessing the impacts

Table 1. Annual Rate of Occurrence of Identified Hazards for Georgetown County, South Carolina

Hazard	Number of Events	Years in Record	Hazard Frequency (% chance/ year)	Data Source
Chemical release—fixed	41	10	410.0	Toxic Release Inventory; EPCRA Tier2; Emergency Response Notification System; U.S. DOT
Chemical release—railroad	6	10	60.0	Emergency Response Notification System; U.S. DOT
Chemical release—roadway	4	10	40.0	Emergency Response Notification System; U.S. DOT
Drought (# drought months)	25	101	24.75	Palmer Drought Severity Index, 1895–1995
Earthquake (# felt)	9–12	298	3.02–4.03	South Carolina Seismic Network, 1698–1995
Floods			1.0/0.2	FEMA, 1995
Hail	10	41	24.39	National Severe Storms Lab, 1955–1995
Hurricane surge-cat. 1	19	111	17.12	SLOSH; National Hurricane Center, 1886–1996
Hurricane surge-cat. 2	18	111	16.22	SLOSH; National Hurricane Center, 1886–1996
Hurricane surge-cat. 3	3	111	2.70	SLOSH; National Hurricane Center, 1886–1996
Hurricane surge-cat. 4	4	111	3.60	SLOSH; National Hurricane Center, 1886–1996
Hurricane surge-cat. 5	0	111	0.01	SLOSH; National Hurricane Center, 1886–1996
Hurricane wind	1–4	111	0.9–3.6	National Hurricane Center, 1886–1996
Thunderstorm wind	48	41	117.07	National Severe Storms Lab, 1955–1995
Tornado	7	46	15.22	National Severe Storms Lab, 1950–1995
Wildfire	3213	15	21420.0	South Carolina Forestry Commission, 1981–1996

of drought accurately. Georgetown County had 25 years of at least moderate drought between 1895 and 1995, or roughly the equivalent of 300 drought months.

Hazard Zone Delineation

The next stage in the process was to delineate each hazard zone and assign the rate of occurrence. Some hazards have well-defined spatial impact areas within the county (e.g., flood plains). Likewise, chemical spills from train accidents normally are confined to those areas surrounding the rail lines, not the entire county. Other hazards are less spatially concentrated. Based on their infrequent occurrence, these hazards often appear to have a random spatial distribution at the county level. For these hazard events (tornadoes, wind events, hail, severe storms), we assumed the hazard zone encompassed the entire county.

Spatially concentrated hazards were approached similarly but first required the delineation of those areas potentially affected. Flooding is perhaps most illustrative. Flood-hazards zones were based on FEMA's Q3 flood data using 100-yr and 500-yr flood zones[3] (Figure 3). Thus, the

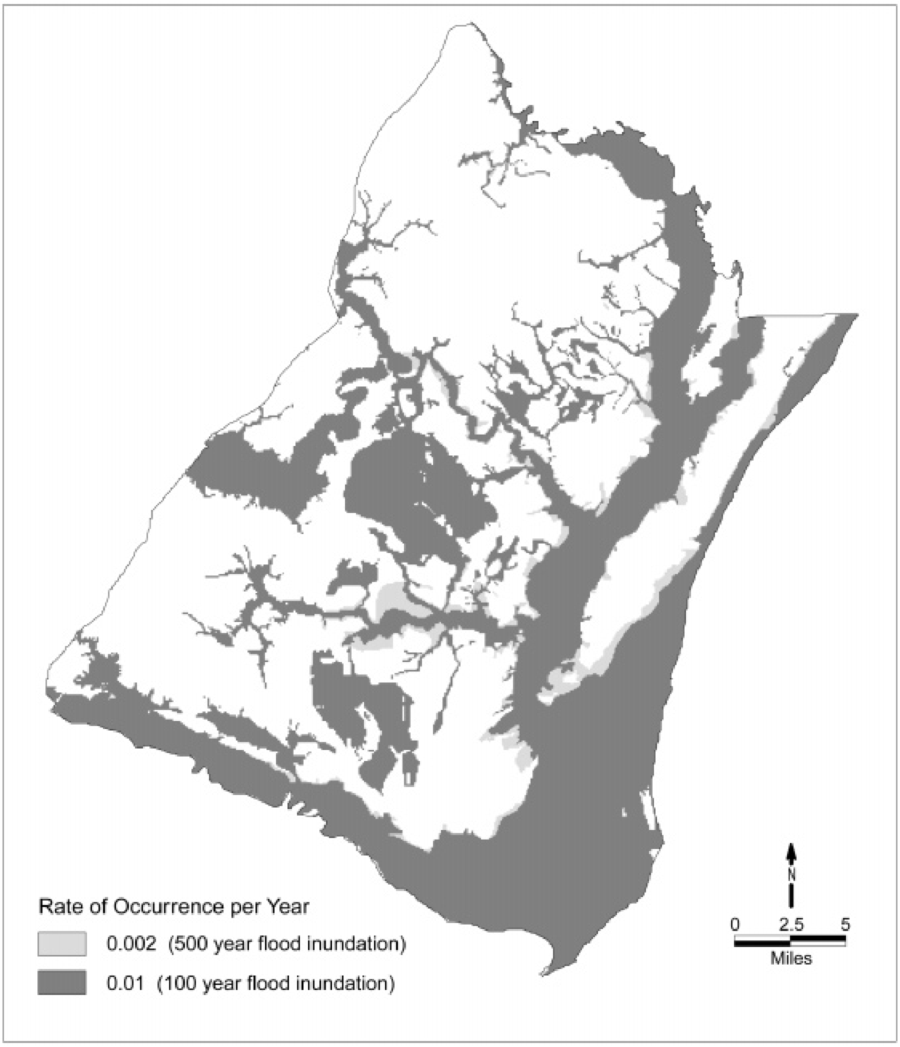

Figure 3. Flood zones in Georgetown County based on the 100-yr and 500-yr flood inundation zones derived from FEMA Q3 data.

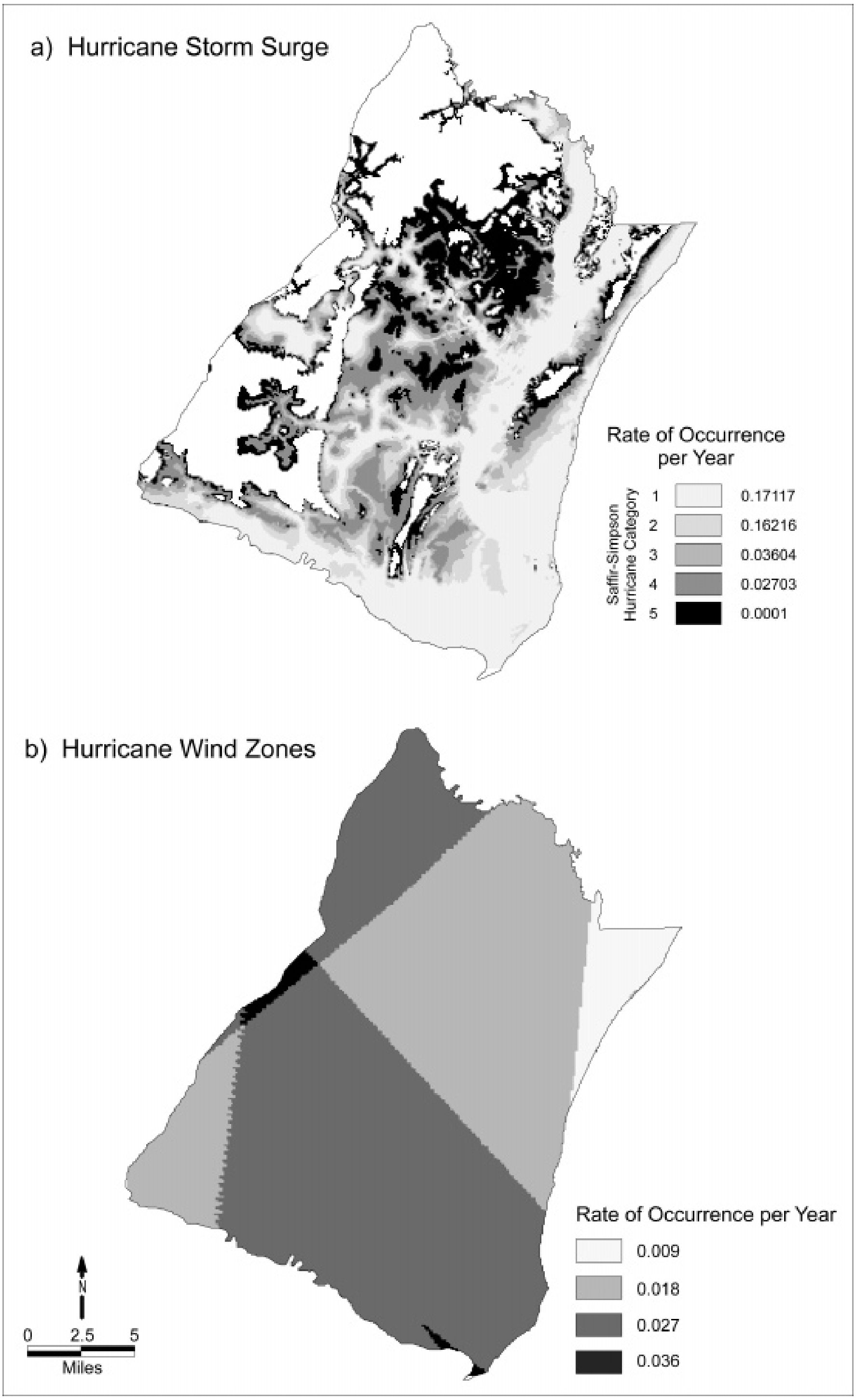

Figure 4. Hurricane hazard zones in Georgetown County based on storm-surge inundation (a) and wind-impact zones (b).

rates of occurrence are implied in these geographic delineations (1 percent chance per year in the 100-yr flood zone; 0.25 percent chance per year in the 500-yr flood zone).

Hurricane hazards have two primary components, storm surge and wind, both requiring spatial delineation. We used the output from the National Hurricane Center's SLOSH[4] model to define hurricane storm-surge hazard areas. The National Hurricane Center uses this model to calculate the areas that potentially will be inundated by storm surge in each Saffir-Simpson[5] scale category. These hazard zones represent the worst-case scenario for each hurricane category (Figure 4a).

Hurricane windfields were derived from modeling historic storm winds using estimated wind speed, direction, duration, and the geographic area affected by the storm (Ramsey et al. 1998). The model used 44 historic hurricanes to determine the spatial extent of windfields (>70-mph sustained winds) (Figure 4b). The duration of wind speeds greater than 70 mph (reported in minutes) provides an estimate of the occurrence rate on a yearly basis.

Hazard zones for hazardous materials releases also had to be constructed (Figure 5). A buffer of one-half mile was created around each railroad and arterial highway segment. This distance is the default isolation distance recommended by

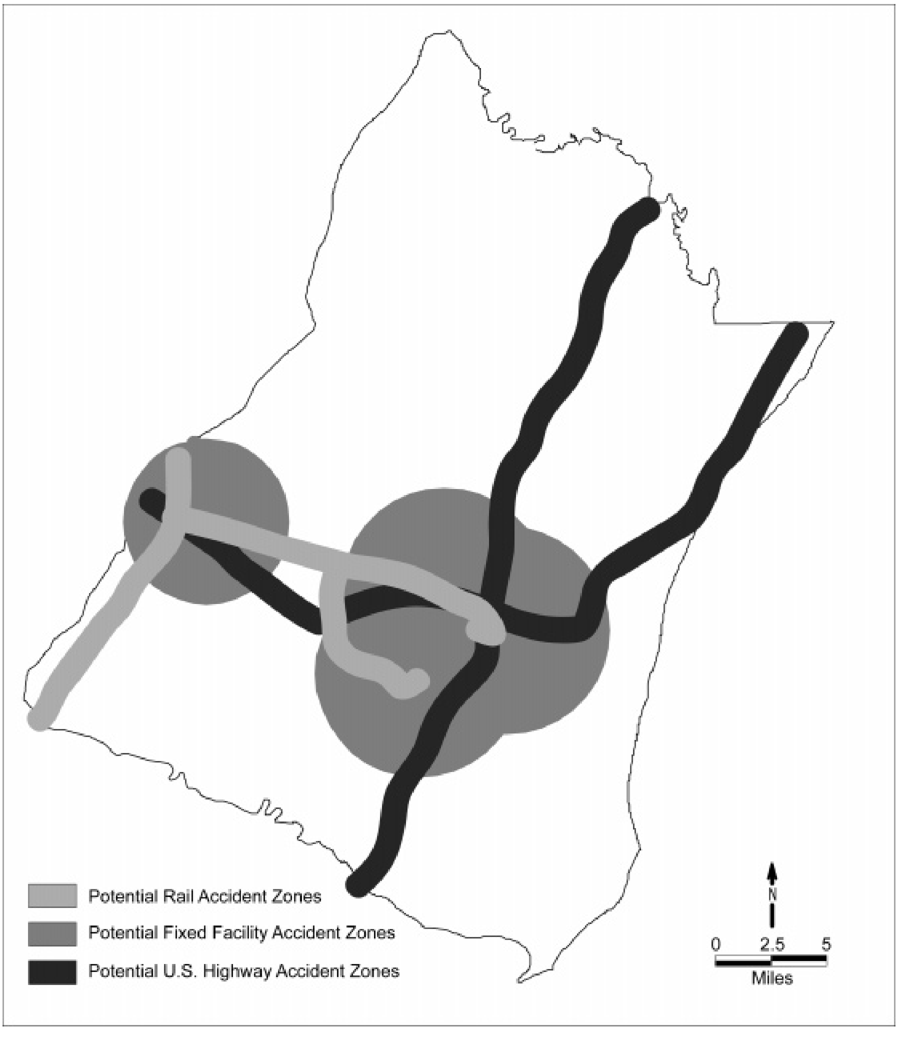

Figure 5. Rail, highway, and fixed-facility chemical accident zones in Georgetown County.

the U.S. Department of Transportation (DOT) for a fire involving hazardous chemicals (USDOT 1993). For fixed sites, a buffer was created equal to the largest protective action distance (PAD) for all chemicals at a given facility. Industrial facilities are required to report annual releases of toxic chemicals through the Toxic Release Inventory that provides data by specific chemical and quantity released (in pounds). These protective action distances range from 0.2 to 5.0 miles, depending on the toxicity of the chemical involved.

More problematic in geographic delineation is the earthquake hazard. Georgetown County has no recorded earthquake epicenters from 1698 to 1995, but 23 earthquakes were felt within the county during this time period (South Carolina Seismic Network 1996). Using "felt earthquakes" as our indicator, the hazard zone was constructed by first entering the epicenter latitude and longitude into a GIS. The South Carolina Seismic Network provides the total area (in square miles) that felt the earthquake. Given the fairly uniform soils and geology of the county, we created a circular buffer around the epicenter to approximate the "felt area." Using GIS, each of the "felt areas" for the 23 earthquakes was overlain and aggregated into a "felt earthquake layer" for the county (Figure 6).

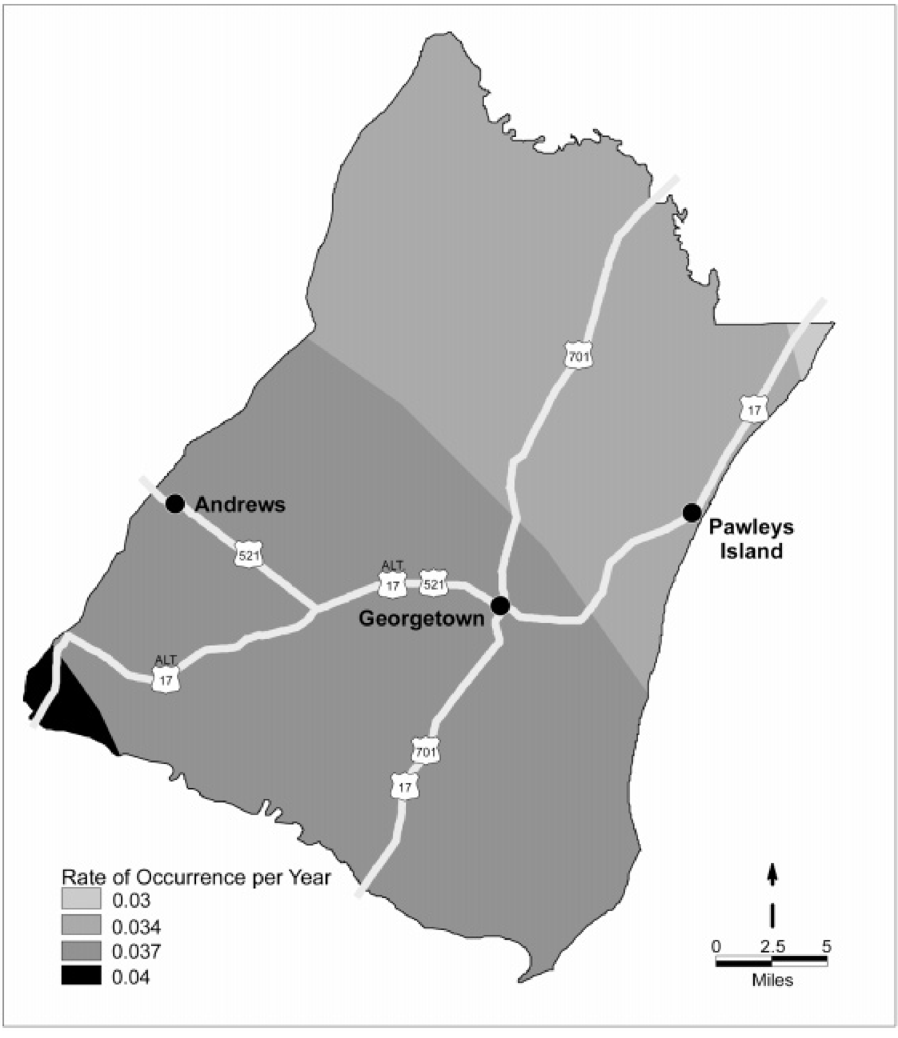

Figure 6. Zones in which earthquakes were felt based on frequency of occurrence per year.

Data Integration

In all, more than 25 different data layers were created in the GIS. Each hazard zone, along with their rate of occurrences, was stored as an individual GIS layer. To assess the total biophysical vulnerability, all the layers were combined into a single composite of intersecting polygons. A biophysical hazard score (based on the rate of occurrence) was assigned to each polygon; these scores were subsequently classed into deciles and mapped to produce a visual display of biophysical vulnerability. A simplified map (using quintiles) shows those portions of the county with the greatest biophysical vulnerability (Figure 7).

Hazardous-material risks are clearly visible on the composite hazards map, represented by the potential evacuation zones surrounding the major facilities, railroads, and highways. Not only is their areal dimension great, but they also have a higher rate of occurrence. The effects of storm surge and flooding are also noticeable, especially within the city of Georgetown and in the coastal portions of the Waccamaw Neck area. Those more geographically diffuse hazards, such as earthquakes, or those that encompass the entire county, such as tornados, are not indi-

Figure 7. Zones of biophysical hazard vulnerability on a 1–5 scale. This composite map represents the overall biophysical vulnerability of the county.

vidually recognizable. They all contribute, however, to the overall biophysical vulnerability of the county.

Defining Social Vulnerability

Social vulnerability "derives from the activities and circumstances of everyday life or its transformations" (Hewitt 1997: 26). Those broad factors that influence many of the fundamental causes of social vulnerability include the following (Blaikie et al. 1994; Institution of Civil Engineers 1995; Cutter et al. 1997; Mileti 1999):

- lack of access to resources, including information and knowledge
- limited access to political power and representation
- certain beliefs and customs
- weak buildings or weak individuals
- infrastructure and lifelines

While these fundamental causes are quite variable in time and space, most research demonstrates that certain demographic and housing characteristics—age, race/ethnicity, income levels, gender, building quality, public infrastructure—are influential in amplifying or reducing overall vulnerability to hazards (Blaikie et al. 1994; Hewitt 1997; Tobin and Montz 1997). Based on the existing literature, we chose to examine those characteristics of the population and their residential environment that contribute to social vulnerability. While not fully explaining the underlying causes of the social vulnerability, these variables do provide an initial metric for operationalizing the concept. The indicators listed in Table 2 were selected to characterize vulnerable populations. All of the social data were taken from the 1990 U.S. Census block statistics, the most recent data available.

Rather than using simple percentages, each social variable was standardized by first determining the ratio of that variable in each census block to the total number of that variable in the county.[6] In Table 3, for example, the number of mobile homes in each census block was tabulated (column 2), as was the number of total mobile homes in the county (column 3). The ratio of the number of mobile homes to the total for the county was computed (column 4). This value (X) was then divided by the maximum value (X) to create an index that ranges from 0 to 1.00. Higher index values indicate greater vulnerability, as in Block A (Table 3). All the social variables were standardized in this manner with the exception of mean house value. In this case, negative numbers were possible, so the absolute value of the difference between block and county values was added (Table 4). The difference between county and block housing was computed (column 4) by taking the county average of mean house value and subtracting the mean house value for each census block. In order to remove negative values, the absolute value of the maximum X (column 4) was added to create Y (column 5). Finally, the ratio of the new value (Y) to the maximum Y generated the mean house value index (column 6). Again, higher values indicate greater vulnerability. As shown in Table 4, Block A is the most vulnerable, followed by Block D, Block C, and then Block B. Once the index values were computed, they were assigned to each block and entered into a GIS as a data layer. It must be reiterated that mean house value is serving as a surrogate for wealth and, thus, resilience. Mean house value is not used to infer that higher priced homes are necessarily less structurally vulnerable. Although those homes may have safety features lacking in homes of lesser value, they are often located in areas that make them more susceptible to damage (e.g., expensive beachfront homes). They also are more likely to be adequately insured.

Table 2. Measures of Socially Vulnerable Populations

Characteristic	Variable
Population and structure	Total population Total housing units
Differential access to resources/greater susceptibility to hazards due to physical weakness	Number of females Number of nonwhite residents Number of people under age 18 Number of people over age 65
Wealth or poverty	Mean house value
Level of physical or structural vulnerability	Number of mobile homes

The same procedure used to develop the composite biophysical vulnerability map was replicated for the social vulnerability mosaic. The index values for each variable were summed

Table 3. Example of Social Vulnerability Indicator–Mobile Homes

Census Block	# of Mobile Homes in Block	# of Mobile Homes in County	Ratio of Block to County (X)	Mobile Home Vulnerability Index (X/ maximum X)
A	125	3,500	0.036	1.00
B	76	3,500	0.022	0.61
C	4	3,500	0.001	0.03
D	21	3,500	0.006	0.17

to arrive at a composite index score for each block, which represents an aggregate measure of social vulnerability. These values were also placed into deciles, but are visually displayed as five categories on the map (Figure 8). As is the case with the biophysical indicators, each individual indicator of social vulnerability can be examined independently; however, it is the summary of all the measures that produces a broad overview of the spatial distribution of social vulnerability within the county. This broad overview has greater functionality for the emergency-management community, who need both the generalized information as well as the specifics.

Two of the most socially vulnerable areas in Georgetown County are near its southern boundary and near the county center, both depicting poor minority areas. Pawleys Island (on Waccamaw Neck) is relatively wealthy and stands out because of the large number of people (both retirees and families with young children) and a higher density of housing units. The vulnerable block near the northern border of the county (Murrells Inlet) is a result of a relatively large elderly population living in mobile home parks. The county's rural regions are less vulnerable because of lower population and housing densities.

The Vulnerability of Places

The components leading to hazard loss (biophysical and social vulnerability) intersect to produce an overall assessment of the vulnerability of Georgetown County. We have intentionally taken a descriptive approach in presenting each element in order to highlight the spatial variability in vulnerability. Since there is no common metric for determining the relative importance of the social vis-à-vis biophysical vulnerability, nor the relative importance of each individual variable (or GIS layer) to the composite picture, this seemed like a prudent course of action.

As the conceptual model suggests, the overlap of hazard zones and social vulnerability produces the spatial variation in overall vulnerability for the county. To achieve the final place vulnerability, the social vulnerability layer was combined with the biophysical vulnerability layer within the GIS. No a priori weights were

Table 4. Calculation of Social Vulnerability Index—Mean House Value

Census Block	Mean House Value($) in Block	Mean House Value($) in County	Value Difference ($) of County and Block (X)	X + Absolute Value of Maximum X (Y)	Mean House Value Vulnerability Score (Absolute value Y/ maximum Y)
A	41,286	75,000	33,714	69,364	1.00
B	110,650	75,000	−35,650	0	0.00
C	76,776	75,000	−1,776	33,874	0.49
D	64,900	75,000	5,100	40,750	0.58

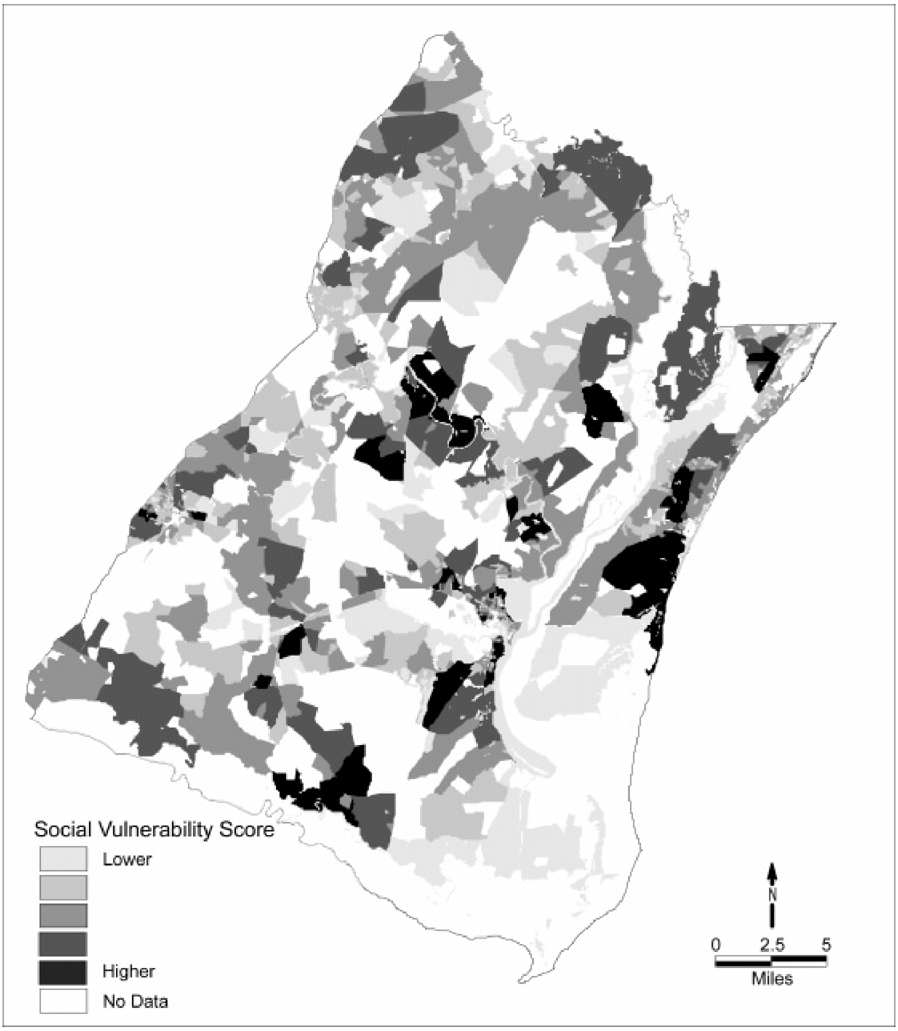

Figure 8. Composite social vulnerability zones in the county.

assigned to the individual layers within the GIS or in the composite social and biophysical indices. Instead, all indicators were treated equally, and we assumed that each had the same relative importance in their contributions to overall vulnerability.[7] Some may argue the appropriateness of this approach, suggesting a weighting scheme based on property at risk or other measures of economic losses. No reliable statistics, however, are available at the present time on annual losses from natural disasters at the national level, let alone at the county level (Mileti 1999). The product of the two index scores (social and biophysical vulnerability) was then reclassified into five categories and mapped.

As can be seen in Figure 9, the most vulnerable areas—the cities of Georgetown, Andrews, and the communities of the Waccamaw Neck—include a moderate level of both hazards and social indicators. Most of the areas of high biophysical vulnerability do not overlap with areas of high social vulnerability. Rather, the overall hazard vulnerability of Georgetown County is a function of medium levels of biophysical risk coupled with medium-to-high levels of social vulnerability. The less vulnerable areas are inland, located away from the county's major industries, transportation corridors, and major waterways. They are also sparsely populated.

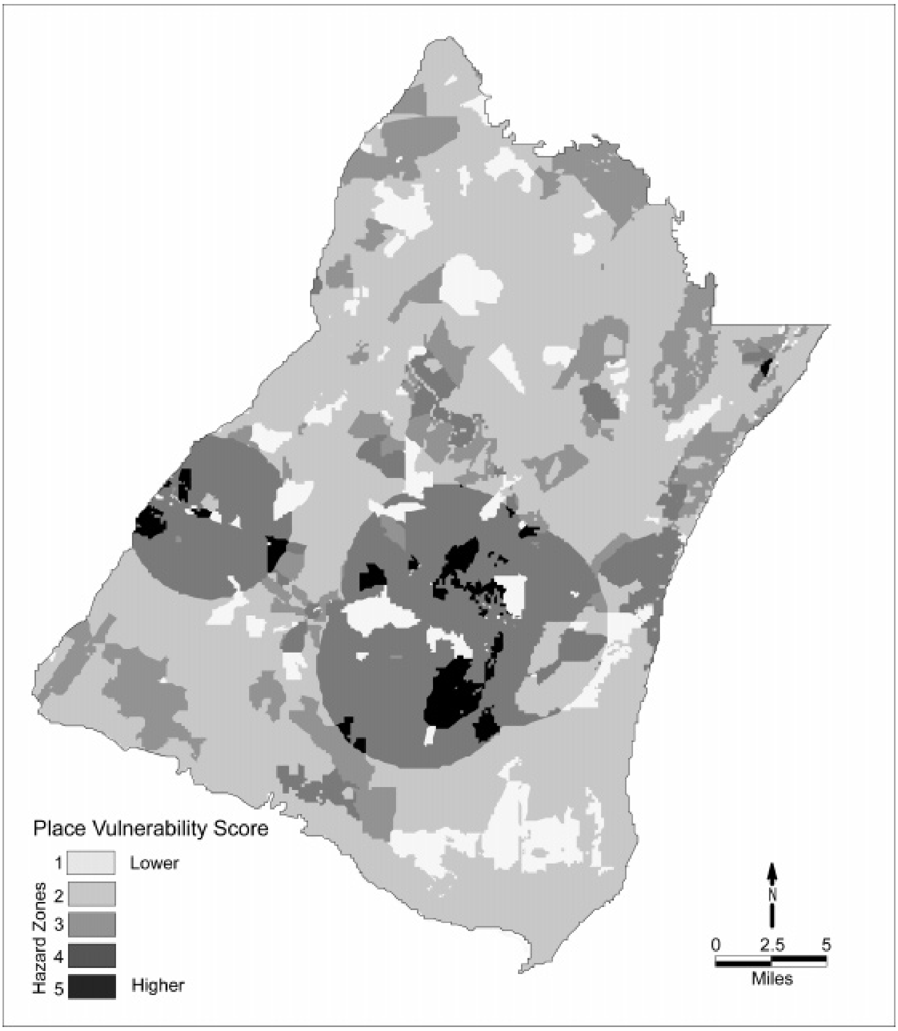

Figure 9. The spatial distribution of overall hazard vulnerability in Georgetown County.

Numerical Estimates of Vulnerability

In addition to the spatial representation of place vulnerability using the GIS, we can also estimate the number of people and structures in each hazard zone utilizing areal interpolation techniques. In this way, we can produce an empirical "estimate" of the potential population or structures at risk either from a singular hazard (Table 5) or from all hazards combined (Table 6). For example, a Category 1 hurricane (on the Saffir-Simpson Scale) would affect 26 percent of the county area, 22 percent of its housing units (single family and mobile homes), but only 8 percent of its population. The mean house value ($71,213), however, is greatest in this Category 1 hurricane hazard zone, so we would anticipate considerable economic loss should a hurricane strike this area. Chemical releases from fixed sites could affect 22 percent of the county area, nearly half of its total population, and 42 percent of its housing units. These same releases would also disproportionately affect children, the elderly, minorities, and women (approximately half of whom live in the affected areas) (Table 5).

We also examined the individual components of social vulnerability based on hazard subregion (Figure 9, Table 6). For example, the most vulnerable area (Hazard Zone 5) contains

Table 5. Percentage of Each Social Indicator Per Specific Hazard Zone

Hazard Zones	% Total Population	% Housing Units	% Mobile Homes	% Age <18	% Age >65	% Nonwhite	% Female	% Area	Average Mean House Value ($)
Chemical release—fixed	49.23	42.09	34.34	51.67	48.41	48.90	49.81	21.97	55,402
Chemical release—rail	19.48	16.88	14.98	21.03	20.26	25.92	20.01	4.75	47,726
Chemical release—road	46.49	49.18	45.37	43.42	55.87	42.88	47.36	9.10	71,421
Drought	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	62,956
Earthquake—low	2.19	5.91	4.56	1.24	2.70	0.17	2.09	0.38	100,510
Earthquake—low/med	36.97	42.98	46.53	33.42	41.06	34.29	36.67	41.09	69,429
Earthquake—med/high	60.59	50.87	48.55	65.05	56.02	65.27	61.02	57.32	48,298
Earthquake—high	0.16	0.11	0.34	0.20	0.12	0.26	0.14	1.21	10,627
Flood—100yr	16.00	25.05	13.65	14.36	19.50	11.40	15.75	42.12	62,506
Flood—500yr	6.29	6.21	4.23	5.79	7.10	3.65	6.26	2.95	78,998
Hail	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	62,956
Hurricane cat. 1	8.12	17.48	4.60	6.39	11.44	4.32	7.95	25.95	71,213
Hurricane cat. 2	8.85	10.43	7.07	7.51	10.52	5.93	8.75	9.65	69,871
Hurricane cat. 3	16.07	15.11	15.11	15.68	17.74	15.17	16.28	8.56	69,124
Hurricane cat. 4	25.12	21.46	23.30	26.32	26.18	30.81	25.61	13.39	61,087
Hurricane cat. 5	13.21	11.73	19.79	13.02	12.30	12.91	12.89	14.06	64,273
Hurricane wind—low	15.33	27.79	24.97	9.80	23.83	6.21	15.15	4.32	116,338
Hurricane wind—low/med	32.76	28.61	30.52	34.43	27.57	36.03	32.66	40.36	57,805
Hurricane wind—med/high	51.47	43.18	43.91	55.33	48.25	57.61	51.76	54.41	42,849
Hurricane wind—high	0.36	0.29	0.58	0.38	0.27	0.14	0.35	0.89	26,600
Severe wind	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	62,956
Tornado	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	62,956
Wildfire	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	62,956

Table 6. Social Vulnerability for Each Hazard Zone

Hazard Zone[a]	Total Population	Housing Units	Mobile Homes	Age <18	Age >65	Non-white	Female	% Area	Average Mean House Value ($)	Total Housing Value ($millions)
1	6,421	2,267	498	1,849	450	3,154	3,217	23.00	42,968	97
2	5,571	1,817	446	1,621	353	3,316	2,703	18.00	44,729	81
3	3,230	2,424	147	753	268	1,532	1,503	30.50	49,715	120
4	9,973	5,212	1,381	2,236	1,173	2,655	4,879	13.50	63,174	329
5	17,806	6,591	777	5,055	1,947	7,746	9,177	15.00	56,062	369
Total	43,001	18,311	3,249	11,514	4,191	18,403	21,479	100.00	n/a	996

[a] In order of vulnerability, from lowest (1) to highest (5).

about 17,000 people, or 41 percent of the county's total population, but only 15 percent of the land area. Similarly, this highly vulnerable region includes 36 percent of the county's housing units, or an estimated $369 million in housing stock that is at risk. As population and development increase in this coastal county, some estimates project a 32-percent population increase by 2005 from 1990 levels, Georgetown County's vulnerability to hazards will surely increase. It is important to anticipate where this vulnerability might be the greatest and whom it might affect the most.

Establishing the Social and Infrastructure Context

The simple overlap of hazard and social-vulnerability zones does not complete the hazard scenario for Georgetown County. The social and infrastructure context must also be established. There are certain elements of each that can contribute to the attenuation or amplification of the vulnerable areas. For instance, vulnerable groups that are distant from evacuation routes or downstream from a dam will be at greater risk. Overlaying the infrastructure over the place-vulnerability may yield valuable information for mitigation planning. For example, an area ranking high in place-vulnerability may contain two daycare centers and be near a known traffic "choke" point on an evacuation route. This information would alert emergency managers that a vulnerable population, such as children, may need to be evacuated, and special steps taken to avert the congestion associated with that particular evacuation route.

Two procedures are involved in establishing the infrastructure context: (1) the identification and collection of special-needs population data, and (2) the determination of key infrastructure and lifelines. Special-needs locations include daycare centers, nursing homes, health centers, hospitals, and schools. These locations were determined through the use of a digital phonebook, a conventional phonebook, and by contacting the local U.S. Post Office. Some facilities were also accurately located by using address-matching software or a global positioning system (GPS). Infrastructure includes roads, structures, utilities, railroads, bridges, dams, airfields, ports, and evacuation/response facilities. These locations were determined in the same manner. The infrastructure, lifelines, and special-needs locations were entered into the GIS and then added to the place-vulnerability layer to create our contextualized place-vulnerability (Figure 10). The mapped presentation of these data illustrate that many of the lifelines are located in highly vulnerable areas, notably evacuation shelters, police/fire stations, and schools. The latter are important from an emergency-response perspective. If a hazard event occurs during the day, additional resources may be needed to relocate a population out of harm's way (time permitting) or to assist in immediate recovery operations. In this respect, the infrastructure amplifies the information on hazard vulnerability. For those slower-onset hazard events that strike the area, severely damaged schools may increase the amount of time it takes the community to return to normal, as parents will not leave school-aged children unattended while they return to work.

It is unlikely that all multiple-hazard events would occur simultaneously, thereby achieving the level of biophysical vulnerability depicted here. There have been instances, however, where natural events such as floods, earthquakes, and hurricanes have ruptured pipelines and damaged facilities, resulting in hazardous-materials releases. Knowledge of the spatial distribution of biophysical and social vulnerability, coupled with a geographic understanding of lifelines, can help counties to better prepare for disasters and to develop mitigation strategies to reduce future losses.

Conclusions

The multifaceted nature of vulnerability demands a thorough consideration of both the biophysical and social systems that give rise to hazards. To understand the potential for loss of property or life from environmental hazards, we also must consider the particular context in which the hazard takes place. Physical hazard exposure and social susceptibility to hazards must be understood within a geographic framework, that is, the hazardousness of a specific place. This uniquely geographical concept considers the threat from all hazards in a given place and provides the opportunity to mitigate several hazards concurrently. By harnessing geographic innovations such as GIS, we have the ability to investigate the spatial nature of multiple hazards and the specific subpopulations that are differentially affected. In this paper, we have pre-

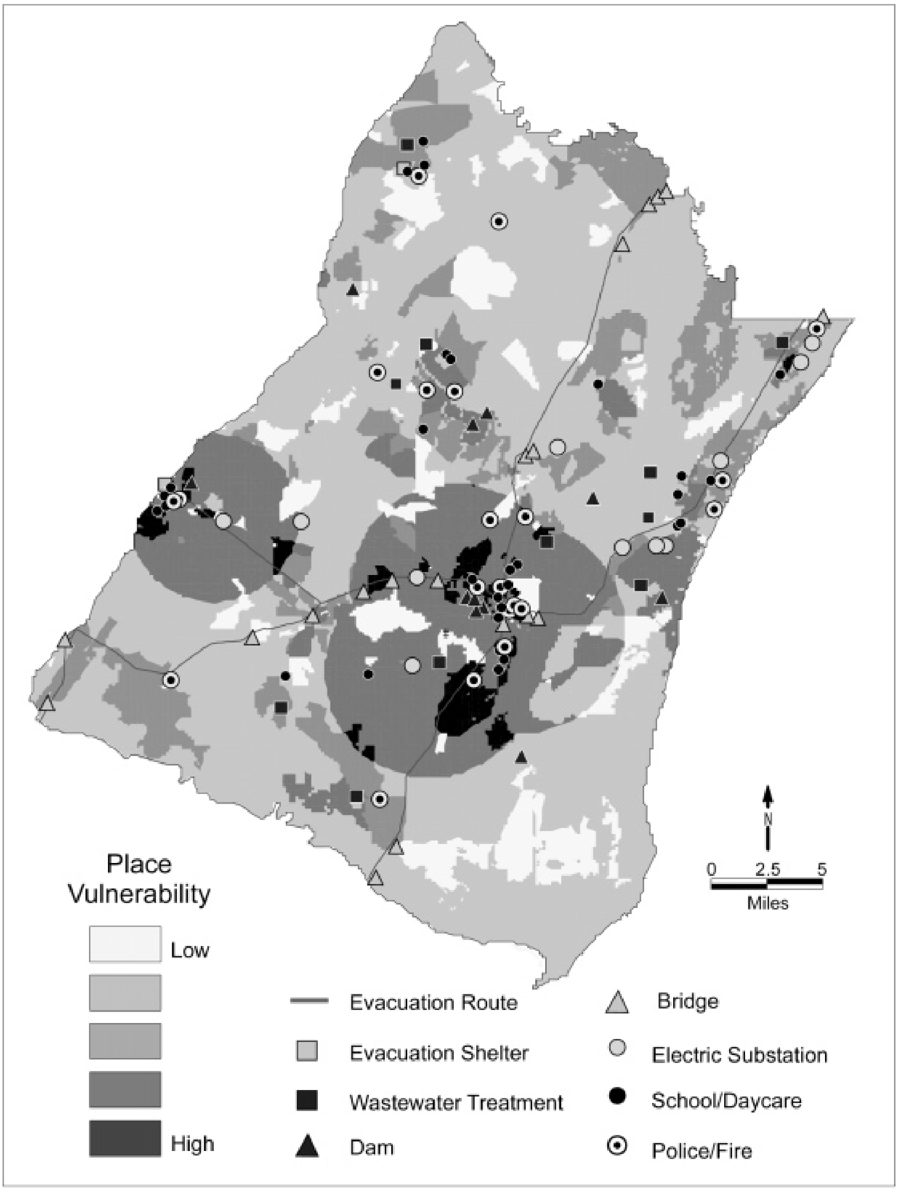

Figure 10. Place-vulnerability, lifelines, and infrastructure. This figure represents the contextualized aspects of place-vulnerability.

sented a conceptual model of vulnerability that includes both biophysical and social dimensions. The usefulness of this descriptive approach and its implementation, using a geographic information system, was explored for Georgetown County, South Carolina.

To determine biophysical vulnerability, we analyzed those hazardous events, both natural and technological, that are likely to occur within a specific geographic area. To do this required an examination of the past history of nine hazards that affected the county, ranging from hurricanes to chemical releases. The likely rate of occurrence for each hazard was assigned within a GIS to the appropriate hazard zone, enabling us to examine the geography of individual hazard zones, as well as those areas that are vulnerable to multiple hazards. In a similar fashion, socially vulnerable areas were identified through a comparative analysis using eight socioeconomic characteristics.

In combining biophysical and social vulnerability, we found a high degree of spatial variability in overall hazard vulnerability within Georgetown County. The most vulnerable places (from a biophysical standpoint) do not always overlap with the most vulnerable populations. Rather, it is the combination of medium levels of biophysical vulnerability coupled with medium-to-high levels of social vulnerability that characterize the overall hazard vulnerability of Georgetown County. This is an important finding as it reflects the likely "social costs" of hazard events to the region. While economic losses would be great for residents in areas delineated in high-risk biophysical hazard zones, their recovery will be facilitated by greater wealth and access to resources. On the other hand, it would take only a moderate hazard event to disrupt the livelihoods and well-being of the majority of county residents and retard their longer-term recovery from disasters.

The research methodology and theoretical conceptualization of hazard vulnerability presented in this paper highlights relevant data for local and state emergency management planners. It is the first step toward developing a baseline all-hazards assessment for places that can be used to evaluate the effectiveness of future mitigation or hazard-reduction plans. The paper illustrates the utility of considering both physical exposure and social susceptibility when determining the hazardousness of places and, as such, provides a template for other integrated place-based hazard studies. The research demonstrates how geographers can and do make significant contributions in the public policy arena. Further, the paper demonstrates the importance of joining the technical aspects of our discipline with theoretical partners in illustrating the power of geographic explanation and its relevance to nature-society interactions.

It is appropriate at this juncture to pose a number of questions. First, how might data issues be resolved to strengthen the analysis? There are some obvious concerns and caveats regarding the difficulty of data acquisition, data coverage, and data representation. Some of the data had good spatial resolution, other datasets less so. A concentrated effort to collect more detailed and geographically referenced data by all those involved in hazard reduction and management will go far in eliminating several of the data difficulties we experienced. In fact, this is one of the primary conclusions of a recently released report assessing the state-of-the-knowledge in hazard research and management (Mileti 1999). There is also a temporal dimension to hazard events that make some months more disaster-prone than others. The issue of seasonal variability in biophysical vulnerability was not addressed here, but could be incorporated into subsequent research that builds upon the approach we suggested. Despite these data concerns, this paper demonstrates that the conceptual model can be successfully implemented and therefore contribute to our understanding of the complexities in determining what makes people and places vulnerable to hazards.

Keeping within the spirit of traditional hazards research, what real-world relevance does this research contribute to a state or local emergency manager? At a county scale, this paper provides local-level emergency managers with a methodology and analytical tool for identifying those areas most vulnerable to hazards within their counties. The paper highlights the importance of identifying hazards with the greatest potential to affect the county and those geographic areas (hazard zones) most likely to suffer when the hazard event does occur. The approach enables the practitioner to view the relative importance of the social aspect of hazards by identifying those social groups who are differentially vulnerable, and to plan accordingly. The greatest challenge to the implementation of this approach to hazard planning and management at the local level is the availability of funds for training and data acquisition. Nevertheless, the usefulness of this methodology as a planning and training tool for emergency preparedness and response is evident.

Finally, some might argue whether the county is the most appropriate or useful scale for this type of hazard analysis. While we used the county as the study area, with census blocks as subunits for the social data, the analysis easily could have been conducted at another scale. Given that most hazard mitigation is local, the county seemed like a prudent choice, especially when the significance of county-wide land use and zoning decisions and emergency preparedness operations are taken into consideration. Caution should be exercised in reducing the size of geographic units, as differences in hazard-occurrence rates between enumeration units may be so negligible that it would be difficult to undertake hazards assessments at the subcounty level. Additional research on the spatial vulnerability of urban areas might prove useful. For example, a metropolitan area-level analysis might be used to determine the regional variation in social vulnerability and biophysical risk in order to develop coordinated responses to hazard events that affect multiple jurisdictions.

The application of the theoretical understanding of human-environment relations, the conceptualization of hazard vulnerability and its complexities, and the use of geographical techniques to spatially represent vulnerability provide powerful selling points for the salience of the discipline to public policy. The research presented here demonstrates the need for and value of broadly trained geographers with a knowledge of both physical and human systems and geographic techniques—skills that are increasingly necessary to solve contemporary problems such as those posed by environmental hazards.

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Notes

1. South Carolina's Gullah community is descendant from West African slaves brought over to work the indigo and rice plantations. The Gullah language, partially derived from the slave era, is still spoken by many rural Blacks along the coast. Gullah culture has distinctive music, foods, and crafts. Blacksmithing that created much of Charleston's ornamental iron-work and the Gullah baskets made of marsh grass and sold in Charleston's Historic City Market are examples of the Gullah material culture that can be seen today (Winberry 1996; Edgar 1998).
2. For a more detailed discussion of data sources and caveats, see Cutter et al. (1997) and Mitchell et al. (1997).
3. FEMA's so-called Q3 flood data is primarily used for planning purposes and not for strict determination of floodways, as is the case for Federal Insurance Rate Maps (FIRM). The Q3 maps are digital generalizations of the FIRM normally done at the county scale (1:24,000). The Q3 maps show floodways for both coastal and riverine environments and represent them as the 100-yr and 500-yr flood inundation zones, but the Q3 data do not have the level of accuracy required for enforcing the National Flood Insurance Program and cannot be used as such.
4. Storm surge is the elevation of the ocean surface resulting from the compound effects of water being pushed shoreward by wind across decreasing depths on a continental shelf, low pressure at the sea surface, tides raising the water level, and winds raising the ocean surface. The SLOSH model (Sea, Lake, Overland Surges from Hurricanes) is a computer simulation developed by the National Weather Service and is used to predict the height of hurricane storm surge. The U.S. Army Corps of Engineers and FEMA contracted with the NOAA National Hurricane Center to calculate the worst-case inundation zones for coastal South Carolina using SLOSH model output. These zones are based upon the Saffir-Simpson hurricane scale. The SLOSH model output has been run for all of the coastal counties (Horry, Georgetown, Charleston, Colleton, Jasper, and Beaufort).
5. The Saffir-Simpson Scale is a measure of hurricane intensity and magnitude based on central pressure (millibars), windspeed (knots), storm surge, and potential damage. Categories range from 1 (minimal) to 5 (catastrophic). The SLOSH model described previously is run multiple times, and its output is combined into the Maximum of Maximum Envelope of High Water (MOMs) for all storms from various directions of the same Saffir/Simpson scale. Depending on the specifications or parameters used in developing the "idealized" storm, there may be subtle changes in the inundation contours. The MOMs used in the Georgetown study were for a fast-moving storm (>25 mph).
6. The social data were standardized by the total count for the entire county (similar to z-scores). This enables us to compare (and thus map) variations from the county-wide average. The social variables are thus transformed from spatially extensive data (simple counts such as the number of mobile homes) to spatially intensive data (proportions or ratios such as the number of mobile homes per block/total number of mobile homes in the county). By keeping the social variables on the same scale (0–1.0), we can spatially compare

blocks with higher or lower values and develop composite indices of social vulnerability.

7. We recognize that all indicators of biophysical risk and social vulnerability are not equal. Nonetheless, the lack of reliable damage estimates (local, state, or national) to use as weights, and the need for simplification, forced us to consider all indicators as making equal contributions to vulnerability. Clearly, additional research is needed to develop weighting schemes for the social and biophysical indicators and to test their relative importance in statistically predicting vulnerability. This, however, is beyond the scope of the present paper.

References

Alexander, D. 1991. Natural Disasters: A Framework for Research and Teaching. *Disasters* 15: 209–26.

———. 1997. The Study of Natural Disasters, 1977-1997: Some Reflections on a Changing Field of Knowledge. *Disasters* 21: 284–304.

Barrows, H. 1923. Geography as Human Ecology. *Annals of the Association of American Geographers* 13: 1–14.

Blaikie, P., and Brookfield, H. 1987. *Land Degradation and Society*. London: Methuen.

———; Cannon, T.; Davis, I.; and Wisner, B. 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. Routledge: London.

Bohle, H. G.; Downing, T. E.; and Watts, M. J. 1994. Climate Change and Social Vulnerability: The Sociology and Geography of Food Insecurity. *Global Environmental Change* 4: 37–48.

Brainard, J. S.; Lovette, A.; and Parfitt, J. P. 1996. Assessing Hazardous Waste Transport Risks Using a GIS. *International Journal of Geographical Information Systems* 10: 831–49.

Burton, I.; Kates, R.; and White, G. F. 1978. *The Environment as Hazard*. Oxford: New York.

———; ———; and ———. 1993. *The Environment as Hazard*, 2nd ed. New York: Guilford Press.

Carrara, A., and Guzzetti, F., eds. 1996. *Geographical Information Systems in Assessing Natural Hazards*. Dordrecht: Kluwer.

Chou, Y. H. 1992. Management of Wildfires with a Geographical Information System. *International Journal of Geographical Information Systems* 6: 123–40.

Cova, T. J., and Church, R. L. 1997. Modeling Community Evacuation Vulnerability Using GIS. *International Journal of Geographical Information Science* 11: 763–84.

Cutter, S. L. 1993. *Living with Risk: The Geography of Technological Hazards*. New York: Edward Arnold.

———. 1995. The Forgotten Casualties: Women, Children, and Environmental Change. *Global Environmental Change* 5: 181–94.

———. 1996. Vulnerability to Environmental Hazards. *Progress in Human Geography* 20: 529–39.

——— and Solecki, W. D. 1989. The National Pattern of Airborne Toxic Releases. *The Professional Geographer* 41: 149–61.

——— and Tiefenbacher, J. 1991. Chemical Hazards in Urban America. *Urban Geography* 12: 417–30.

———; Mitchell, J. T.; and Scott, M. S. 1997. Handbook for Conducting a GIS-Based Hazards Assessment at the Local Level. Report, South Carolina Emergency Preparedness Division, and Hazards Research Laboratory, Department of Geography, University of South Carolina.

Dasgupta, P. 1995. Population, Poverty, and the Local Environment. *Scientific American* 272: 40–45.

Douglas, Mary, and Wildavsky, Aaron. 1982. *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. Berkeley: University of California Press.

Dow, K. 1992. Exploring Differences in Our Common Future(s): The Meaning of Vulnerability to Global Environmental Change. *Geoforum* 23: 417–36.

Edgar, W. 1998. *South Carolina: A History*. Columbia, SC: University of South Carolina Press.

Emani, S.; Ratick, S. J.; Clarke, G. E.; Dow, K.; Kasperson, J. X.; Kasperson, R. E.; Moser, S.; and Schwarz, H. E. 1993. Assessing Vulnerability to Extreme Storm Events and Sea-level Rise using Geographical Information Systems (GIS). *GIS/LIS '93 Proceedings* 201–09. Bethesda, MD: ACSM, ASPRS, AM/FM, AAG, URISA.

Enarson, E., and Morrow, B. 1998. *The Gendered Terrain of Disaster*. Praeger: New York.

Federal Emergency Management Agency (FEMA). 1995. *National Mitigation Strategy: Partnerships for Building Safer Communities*. Washington: Government Printing Office.

———. 1997. *Multi-Hazard Identification and Risk Assessment*. Washington: Government Printing Office.

——— and National Emergency Management Association. 1997. *State Capability Assessment for Readiness (CAR)*. Report Version 1, Washington: Government Printing Office.

Fothergill, A. 1996. Gender, Risk, and Disaster. *International Journal of Mass Emergencies and Disasters* 14(1): 33–56.

Hewitt, K., ed. 1983. *Interpretations of Calamity*. Winchester, MA: Allen & Unwin.

———. 1997. *Regions of Risk: A Geographical Introduction to Disasters*. Essex: Longman.

——— and Burton, I. 1971. *The Hazardousness of a Place: A Regional Ecology of Damaging Events*. Toronto: Department of Geography, University of Toronto.

Hodgson, M. E., and Palm, R. 1992. Attitude and Response to Earthquake Hazards: A GIS Design for

Analyzing Risk Assessment. *GeoInfoSystems* 2(7): 40–51.

Institution of Civil Engineers. 1995. *Megacities: Reducing Vulnerability to Natural Disasters*. London: Thomas Telford Press.

Interagency Floodplain Management Review Committee. 1994. *Sharing the Challenge: Floodplain Management into the 21st Century*. Washington: Government Printing Office.

Johnson, B. B., and Covello, V. T. 1989. *The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception*. Dordrecht: D. Reidel Publishing.

Johnson, J., and Zeigler, D. 1986. Evacuation Planning for Technological Hazards: An Emerging Imperative. *Cities* 3: 148–56.

Jones, A. C. 1995. Improvement of Volcanic Hazard Assessment Techniques Using GIS: A Case Study of Mount Etna, Sicily. In *Innovations in GIS 2*, ed. P. Fisher, pp. 223–31. London: Taylor and Francis.

Kasperson, J. X.; Kasperson, R. E.; and Turner, B. L. III, eds. 1995. *Regions at Risk: Comparisons of Threatened Environments*. Tokyo: United Nations University Press.

Kasperson, R. E.; Renn, O.; Slovic, P.; Brown, H. S.; Emel, J.; Goble, R.; Kasperson, J. X.; and Ratick, S. 1988. The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis* 8: 177–87.

Kates, R., and Burton, I., eds. 1986. *Geography, Resources, and Environment*, vol. 1. Chicago: University of Chicago Press.

——— and Kasperson, J. X. 1983. Comparative Risk Analysis of Technological Hazards (A Review). *Proceedings of National Academy of Science USA* 80: 7027–38.

Kates, R.; Hohenemser, C.; and Kasperson, J. X. 1985. *Perilous Progress: Managing the Hazards of Technology*. Boulder, CO: Westview Press.

Krimsky, S., and Golding, D. eds. 1992. *Social Theories of Risk*. Westport, CT: Praeger.

Lindell, M. K., et. al. 1997. Adoption and Implementation of Hazard Adjustments. *International Journal of Mass Emergencies and Disasters* 15: 323–453.

Liverman, D. 1990a. Vulnerability to Global Environmental Change. In *Understanding Global Environmental Change*, ed. R. Kasperson, et al. Worcester, MA: Clark University.

———. 1990b. Drought in Mexico: Climate, Agriculture, Technology and Land Tenure in Sonora and Puebla. *Annals of the Association of American Geographers* 80: 49–72.

Lowry, J. L. Jr.; Miller, H. J.; and Hepner, G. F. 1995. A GIS-based Sensitivity Analysis of Community Vulnerability to Hazardous Contaminants on the Mexico/U.S. Border. *Photogrammetric Engineering and Remote Sensing* 61: 1347–59.

McMaster, R. 1988. Modeling Community Vulnerability to Hazardous Materials Using Geographic Information Systems. *Proceedings, 3rd International Symposium on Spatial Data Handling* 143–56. Columbus, OH: Ohio State University.

Marcello, B. 1995. FEMA's New GIS Reforms Emergency Response Efforts. *GIS World* 8(12): 70–73.

Mileti, D. 1999. *Designing Future Disasters: An Assessment and Bolder Course for the Nation*. Washington: Joseph Henry Press.

Mitchell, J. K., ed. 1998. *The Long Road to Recovery: Community Responses to Industrial Disaster*. Tokyo: United Nations University Press.

———; Devine, N.; and Jagger, K. 1989. Contextual Model of Natural Hazard. *The Geographical Review* 79: 391–409.

Mitchell, J. T.; Scott, M. S.; Thomas, D. S. K.; Cutler, M.; Putnam, P. D.; Collins, R. F.; and Cutter, S. L. 1997. Mitigating against Disaster: Assessing Hazard Vulnerability at the Local Level. *GIS/LIS '97 Proceedings* 563–71. Bethesda, MD: ACSM, ASPRS, AM/FM, AAG, URISA.

Monmonier, M. 1997. *Cartographies of Danger: Mapping Hazards in America*. Chicago: University of Chicago Press.

National Research Council (NRC). 1991. *A Safer Future: Reducing the Impacts of Natural Disasters*. Washington: National Academy Press.

O'Brien, P., and Mileti, D. 1992. Citizen Participation in Emergency Response Following the Loma Prieta Earthquake. *International Journal of Mass Emergencies and Disasters* 10: 71–89.

O'Keefe, P.; Westgate, K.; and Wisner, B. 1976. Taking the Naturalness out of Natural Disasters. *Nature* 260: 566–67.

Oliver-Smith, A. 1986. Disaster Context and Causation: An Overview of Changing Perspectives in Disaster Research. *Natural Disasters and Cultural Responses: Studies in Third World Societies* 36: 1–34.

Palm, R. 1990. *Natural Hazards: An Integrative Framework for Research and Planning*. Baltimore: Johns Hopkins University Press.

——— and Carroll, J. 1998. *Illusions of Safety: Culture and Earthquake Hazard Response in California and Japan*. Boulder, CO: Westview Press.

Palmer, W. 1965. *Meteorological Drought*. Research Paper 45. Washington: U.S. Weather Research Bureau.

Perry, R., and Lindell, M. 1991. The Effects of Ethnicity on Evacuation Decision Making. *International Journal of Mass Emergencies and Disasters* 9: 47–68.

Platt, R. 1995. Lifelines: An Emergency Management Priority for the United States in the 1990s. *Disasters* 15: 172–76.

Pulido, L. 2000. Rethinking Environmental Racism: White Privilege and Urban Development in Southern California. *Annals of the Association of American Geographers* 90: 12–40.

Quarantelli, E. L. 1988. Disaster Studies: An Analysis of the Social Historical Factors Affecting the Development of Research in the Area. *International Journal of Mass Emergencies and Disasters* 5: 285–310.

Ramsey, E. W. III; Hodgson, M. E.; Sapkota, S. K.; Laine, S. C.; Nelson, G. A.; and Chappell, D. K. 1998. Forest Impact Estimated with NOAA AVHRR and Landsat TM Data Related to a Predicted Hurricane Wind Field Distribution. Manuscript.

Rogers, G. C., Jr. 1970. *The History of Georgetown County, South Carolina*. Columbia: University of South Carolina Press.

Schneider, S. K. 1995. *Flirting with Disaster: Public Management in Crisis Situations*. Armonk, NY: M.E. Sharpe.

Sorenson, J. H.; Carnes, S. A.; and Rogers, G. O. 1992. An Approach for Driving Emergency Planning Zones for Chemical Munitions Emergencies. *Journal of Hazardous Materials* 30: 223–242.

Sorenson, John H.; Soderstrom, J.; Copenhaver, E.; Carnes, S.; and Bolin, R. 1987. *Impacts of Hazardous Technology: The Psycho-social Effects of Restarting TMI-1*. Albany: State University of New York Press.

South Carolina Budget and Control Board. 1997. *South Carolina Statistical Abstract*. Columbia: South Carolina Budget and Control Board.

South Carolina Seismic Network. 1996. *South Carolina Earthquakes, 1698–1995*. Columbia: University of South Carolina.

Susman, P.; O'Keefe, P.; and Wisner, B. 1983. Global Disasters, a Radical Interpretation. In *Interpretations of Calamity*, ed. K. Hewitt, pp. 263–83. Boston: Allen and Unwin.

Tobin, G., and Montz, B. 1997. *Natural Hazards: Explanation and Integration*. Guilford Press: New York.

Torry, W. 1979. Hazards, Hazes, and Holes: a Critique of the *Environment as Hazard* and General Reflections on Disaster Research. *Canadian Geographer* 23: 368–83.

U.S. Department of Transportation (USDOT). 1993. *Emergency Response Guidebook*. Washington: Government Printing Office.

U.S. General Accounting Office (USGAO). 1995. *Hazardous and Nonhazardous Waste: Demographics of People Living Near Waste Facilities*. Washington: Government Printing Office.

Waccamaw Regional Planning and Development Council. 1997. *Georgetown County Comprehensive Plan*. Georgetown, SC.

Wadge, G.; Wislocki, A.; and Pearso, E. J. 1993. Spatial Analysis in GIS for Natural Hazard Assessment. In *Environmental Modelling with GIS*, ed. M.F. Goodchild, B.O. Parks, and L.T. Steyaert, pp. 332–38. Oxford: Oxford University Press.

Watts, M. 1983. On the Poverty of Theory. In *Interpretations of Calamity*, ed. K. Hewitt, 231–62. Boston: Allen and Unwin.

White, G. F. 1945. *Human Adjustments to Floods*. Department of Geography Research Paper 29. Chicago: University of Chicago Press.

———. 1964. *Choice of Adjustments to Floods*. Department of Geography Research Paper 93. Chicago: University of Chicago Press.

——— and Haas, J. E. 1975. *Assessment of Research on Natural Hazards*. Cambridge: MIT Press.

Wilhite, D., and Easterling, W. eds. 1987. *Planning for Drought: Toward a Reduction of Societal Vulnerability*. Boulder, CO: Westview Press.

Winberry, J. 1996. Gullah: People, Language, and Culture of South Carolina's Sea Islands. In *Snapshots of the Carolinas: Landscapes and Cultures*, ed. G. G. Bennett, pp. 11–16. Washington: Association of American Geographers.

Yarnal, B. 1994. Socioeconomic Restructuring and Vulnerability to Environmental Hazards in Bulgaria. *Disasters* 8: 95–106.

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