11-30-2000

MODELING COMMUNITY RISK AND VULNERABILITY TO MULTIPLE NATURAL HAZARDS: HILLSBOROUGH COUNTY, FLORIDA

Christopher T. Emrich
University of South Florida

Office of Graduate Studies
University of South Florida
Tampa, Florida

CERTIFICATE OF APPROVAL

Master's Thesis

This is to certify that the Master's Thesis of

CHRISTOPHER T. EMRICH

with a major in Geography has been approved
for the thesis requirements on November 30, 2000
for the Master of Arts degree

Examining Committee:

Major Professor: Graham A. Tobin, Ph.D.

Member: Robert Brinkmann, Ph.D.

Member: Steven Reader, Ph.D.

MODELING COMMUNITY RISK AND VULNERABILITY TO MULTIPLE NATURAL HAZARDS: HILLSBOROUGH COUNTY, FLORIDA

by

CHRISTOPHER T. EMRICH

A thesis submitted in partial fulfillment
of the requirements for the degree of
Masters of Arts
Department of Geography
College of Arts and Sciences
University of South Florida

December 2000

Major Professor: Graham A. Tobin, Ph.D.

ACKNOWLEDGMENTS

I would like to express my most sincere gratitude to the many individuals who have assisted me during my quest to produce this thesis. In particular, I would like to thank Dr. Graham A. Tobin for his guidance, understanding, and never ending support throughout this project. Sincere thanks also go to Dr. Brinkmann for his insight and contributions throughout my degree program, and to Dr. Reader, for his patience, support and helpful assistance with many of my GIS applications.

In addition, I would like to acknowledge all of the staff and faculty of the USF Geography department, especially Freddie Williams, for her open door policy and willingness to listen when I needed to talk.

A special thanks is given to all of the unnamed individuals, without the help of, this thesis would never have been completed.

Most of all, I would like to thank my family and my girlfriend Laurie, who have been patient and understanding, and most especially loving throughout all of my years, but especially compassionate and encouraging while I pursued my degree.

Table of Contents

List of Tables

List of Figures

MODELING COMMUNITY RISK AND VULNERABILITY TO MULTIPLE NATURAL HAZARDS: HILLSBOROUGH COUNTY, FLORIDA

by

CHRISTOPHER T. EMRICH

An Abstract

of a thesis submitted in partial fulfillment
of the requirements for the degree of
Masters of Arts
Department of Geography
College of Arts and Sciences
University of South Florida

December 2000

Major Professor: Graham A. Tobin, Ph.D.

Multiple hazard risk and vulnerability are two topics that are at the forefront of hazards research that looks at the hazardousness of place. However, no definitive framework that encapsulates measures of both risk and vulnerability into hazards theory has been developed. Indeed, risk and vulnerability have been used interchangeably. Consequently, populations often encounter high risk environments with little understanding of ways to limit vulnerability. The situation is aggravated by increasing populations and concomitant development of high risk areas. Hillsborough County, Florida, is perhaps the archetype of this problem, having experienced rapid urban growth while giving scant attention to the hazardousness of the environment.

This research, therefore, looks at the hazardousness of place, focusing specifically on risk and dynamic social conditions of vulnerability. Three goals were identified: the first was to understand spatial patterns of risk from multiple natural hazards by examining parameters of the physical environment; the second was to develop a quantitative index of vulnerability within the context of natural hazards differentiated over space; and the third sought to model the combined effects of risk and vulnerability.

Hillsborough County, Florida, was used as the research area. Data on risk from extreme hazardous events, including, wind damage, storm surge, flooding, sinkholes, and hurricanes, were collected from the Arbitrator of Storms (TAOS) files available for the state of Florida. Socioeconomic data for evaluating vulnerability were obtained from Geographic Information Systems (GIS) coverages of the 1990 census. These data included statistics on population density, gender, age, house value, housing density, house structure, and renter occupancy, which were aggregated to develop an index of vulnerability. These various parameters were then used to determine the spatial pattern of hazardousness in Hillsborough County based on census block groups.

Results showed that high hazard risk extended far beyond coastal areas and that virtually all census blocks in the county had some element of risk. The social vulnerability analysis exhibited different spatial patterns with several blocks revealing very high levels of community vulnerability. These areas did not conform exclusively to those categorized as low income. In combination, five census blocks in different parts of the county were identified and shown to have both high risk and high vulnerability.

Thus, combining risk and vulnerability provided a different picture of the hazard problem and should be the focus of further research. From an academic perspective it is now important to test these findings under more rigorous conditions to see if the model stands in other hazard environments. In addition, the findings from the model can also be useful to planners and managers as they consider how to respond to hazards. Identifying vulnerable areas prior to disaster events would greatly facilitate efficient responses.

Abstract Approved: ______________________________

Major Professor: Graham A. Tobin, Ph.D.
Professor, Department of Geography

Date Approved: Dec 6th, 2000

Chapter One

Background

The Problem Identified

Despite a millenia-long struggle with natural hazards, vulnerability to natural hazards remains and in some areas is increasing (El-Sabh 1988). Part of the problem is that society is continually changing and generating new and different risks. Other key factors include the variability of climate, poor memories, and inadequate planning and assessment procedures. To address this, public policy makers have sought to anticipate the unexpected in order to reduce the risk to human life and safety posed by intermittently occurring natural and human-generated hazard events (Petak and Atkisson 1982).

It is against this background that this thesis will determine the extent to which people in Hillsborough County are exposed and vulnerable to multiple natural hazards. To this end, the purpose of this thesis is to present

i. the problem and the context in which the hazards are identified

ii. a discussion of the available hazards literature

iii. a methodology and theoretical framework to be undertaken for examining the risk and vulnerability of census block groups in Hillsborough county to multiple natural hazards.

iv. the outcomes and comment on data analysis.

Along these lines, the following questions are examined in order to develop a full understanding of community risk and vulnerability to multiple natural hazards in Hillsborough County, Florida -

1. How have the census blocks in Hillsborough County
   a. been classified at risk to individual natural hazards?
   b. been classified at risk to multiple natural hazards?
   c. been assessed for characteristics of vulnerability to the effects of natural hazards?
2. What is the current risk of census blocks in Hillsborough County to individual natural hazards?
3. What is the current risk of census blocks in Hillsborough County to multiple natural hazards?
4. What are the most important characteristic that influence vulnerability to individual and multiple natural hazards?
5. What is the current vulnerability of people in Hillsborough County to multiple natural hazards?

Unfortunately, the multiple hazard perspective is rarely adopted in assessing hazardousness or riskiness (Tobin and Montz 1997) . This statement defines the true purpose for this research. As stated by Hewitt and Burton (1971, 30), "While many hazards are compound or multiple, most geophysical measurements are of singular elements (e.g., wind, rainfall) and, generally of one or two specific parameters for those elements." A major gap in the literature exists in the area of multiple hazard risk and vulnerability assessment. The information gathered through this research will help policy makers, private sector risk managers and even homeowners decide what actions should be taken to prevent and prepare for potential disaster.

Hillsborough County's Demographic and Socioeconomic Makeup

Florida has become the fastest growing state in the nation, and Hillsborough County, shown in Figure 1, has grown from 646,900 in 1980 to 892,600 in 1995 and its projected population growth for 2010 is 1,085,500 (US Bureau of Census) (See Figure 2). An overview of the demographic makeup of Hillsborough County shows that the county had 834,054 residents in 1990. By 1993, the population had grown to 866,134, making it the fourth most populated county in the state. Natural change accounted for a 20,660 increase in the number of residents, while migration was responsible for 11,420. Population projections for the year 2000 place the Hillsborough County population at 959,694 residents (US Bureau of Census).

The majority of residents in Hillsborough County, 89.2%, live in urban areas. In 1990, the breakdown by racial category for the State of Florida was 83.1% white and 13.6% black. This places Hillsborough County slightly below the state averages with an 82.8% white population and a 13.2% black population. In Hillsborough County, 0.3% persons were reported to be Native American and 1.4% Asian. In addition 12.8% of population was reported being of Hispanic origin, slightly above the state average of 12.2% of the total population. It should be noted that this category pertains to ethnic origin. Persons of Hispanic heritage may be of any race. In addition Hillsborough County

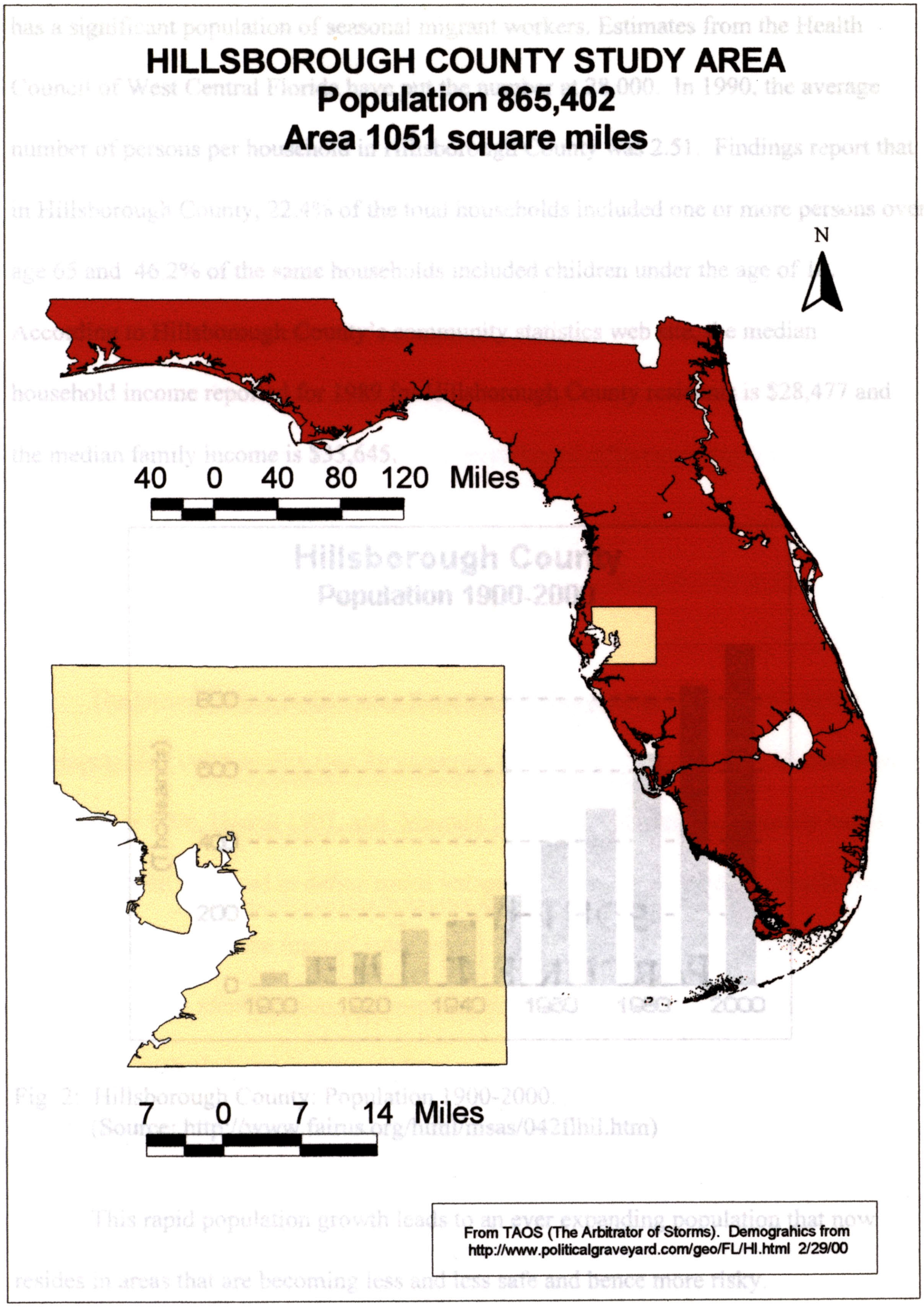

Fig. 1: Hillsborough County Study Area

has a significant population of seasonal migrant workers. Estimates from the Health Council of West Central Florida have put the number at 28,000. In 1990, the average number of persons per household in Hillsborough County was 2.51. Findings report that in Hillsborough County, 22.4% of the total households included one or more persons over age 65 and 46.2% of the same households included children under the age of 18. According to Hillsborough County's community statistics web site, the median household income reported for 1989 for Hillsborough County residents is $28,477 and the median family income is $33,645.

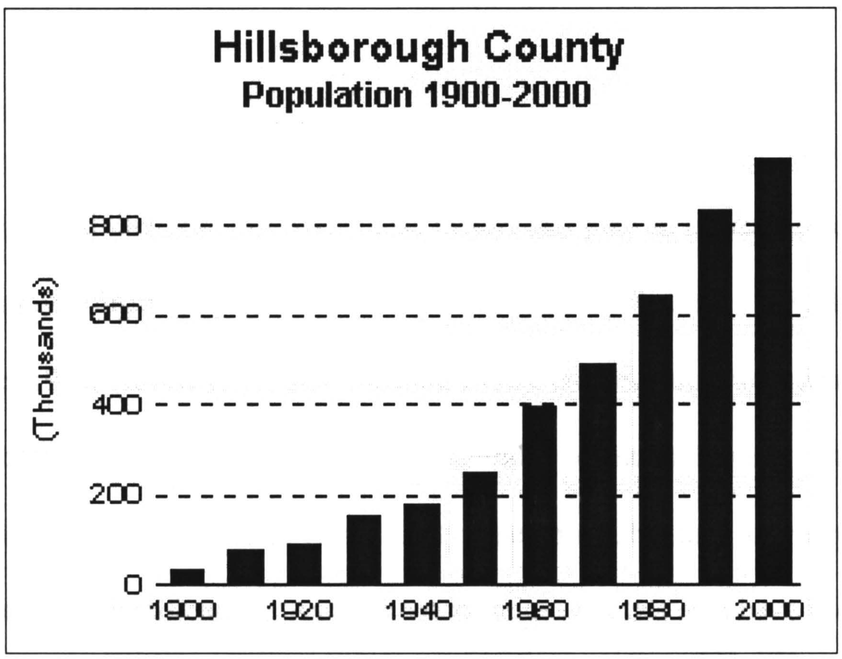

Fig. 2: Hillsborough County: Population 1900-2000.
(Source: http://www.fairus.org/html/msas/042flhil.htm)

This rapid population growth leads to an ever expanding population that now resides in areas that are becoming less and less safe and hence more risky. Accompanying this risk potential is a certain level of vulnerability to disaster. This vulnerability, a term with numerous meanings, has been an issue in which there has been limited research, and thus very few answers. The definition of vulnerability is discussed in detail below, but it should be noted at this juncture that risk and vulnerability are not synonymous. Nevertheless, however the term is identified, at the beginning of the 21st century, society is facing additional threats and risks, which may mean dealing with new types of hazards and disasters. The disasters of the future may or may not be bigger or worse, but they are likely to be more complex and require more sophistication in response and recovery (Rubin 1998). In essence, vulnerability of different sectors of society may also change.

Significance of this study

The hazard literature discusses those factors that play an intricate role in the development of vulnerability (see for example, the work by Susman 1983, Blaikie *et al.* 1994, Cutter 1996, Hewitt 1997, and Mustafa 1998), but only one theoretically based model has been proposed to define social vulnerability to natural hazards. Studies have been completed along the lines of vulnerability assessment, but they are more often than not a form of risk identification. Assessment techniques in this area have become more precise, yet multiple hazards have not been researched thoroughly (Tobin and Montz 1997). Although the scientific basis for risk assessment is often uncertain and the public and its representatives have often been confused by its use in regulatory decisions, the U.S. Environmental Protection Agency currently uses a variety of risk assessment techniques to set priorities, tailor regulations, and make decisions at particular sites (Russell *et al.* 1987). Therefore, it is argued that in order for the continued growth in population to survive amidst catastrophe, there must be a quantitative, interdisciplinary explanation of multiple hazard risk and vulnerability assessment.

This study represents a preliminary investigation into developing a quantitative method for assessing multiple hazard risk and vulnerability. The outcomes of this research will allow policy makers and city planners to more easily identify those areas that are and will be the most vulnerable to and most at the most risk from natural hazards. Based on a theoretical framework that establishes actual vulnerability and risk down to the block level, other researches will have the tools necessary to complete analyses of areas that, as of yet, have been too complicated to conceptualize. Vulnerability will become an issue that is better understood and thus more manageable as an element of disaster research and mitigation. Policy makers, planners and home owners will be able to utilize this research for risk and vulnerability management as well as personal awareness of one's surroundings and current living conditions.

Chapter Two

Literature Review

Introduction

Numerous studies were examined in an attempt to look at the current definitions of risk and vulnerability in academic and government circles. In addition, literature was reviewed in order to understand the current level of natural hazard risk assessment procedures and human vulnerability assessment protocols. In relation to the problem undertaken, the difficulty in the review of the literature was locating studies dealing with multi-hazard vulnerability assessment methodology and multi-hazard risk assessment methodology.

Risk - What is it?

"The meaning of risk has always been fraught with confusion and controversy" (Glickman and Gough 1990, 30). There seems no more appropriate statement than this to convey the message surrounding the meaning of the term risk. The word 'risk' has so many differing uses in the study of natural hazards and involves a vast number of disciplines. Lines of communication have been crossed and varying definitions of natural hazard terminology have been created and accepted by different disciplines. Indeed, Fischhoff *et al.* (1981) state that some misunderstandings between experts and lay people seem to arise from these inconsistent definitions of risk. Many hazards take us into hazy areas where the facts of the matter, the shape of the problem we should be managing, and even the outcomes we want are unclear. The above argument seems to be the case at hand when dealing with natural hazard risk. Many influential authors define risk using terminology that could, and does, cause misinterpretation of the true meaning of risk.

Crouch and Wilson (1982) indicate that risk is defined simply as the probability of an event multiplied by the severity of that event. This understanding of the meaning of risk seems severely oversimplified in the context of natural hazards, yet it, along with many other definitions, have been allowed to remain in the forefront of hazard research. Along with Crouch and Wilson, there are other authors who view risk in terms of probabilities. Cutter (1996, 1) stated that risk is the likelihood or probability that an event will occur. More common today is the definition of risk as the probability of occurrence for an undesirable outcome (Ritter 1981). Tobin and Montz (1997, 282) define risk as probability of occurrence multiplied by vulnerability. Often, risk is associated with loss or damage of some kind, when in fact, risks are frequently taken and closely linked with gain and prosperity. The use of the term probability in the definition of risk may relate the untrue statement that risks are based purely on chance.

According to the United Nations Disaster Relief Organization (UNDRO), risk is defined as loss divided by unit time, or in other words frequency, which is equal to event per unit time, multiplied by magnitude, which is equal to loss per event. In other words, according to the definition of risk presented by UNDRO, the risk of a single event would be simply computed by multiplying the magnitude of that event by its frequency. UNDRO takes a slightly different stance on the meaning of risk by looking at it from an economic viewpoint, rather than a social or physical one. Once again, this is a different approach to a topic that appears at the surface to be relatively simple to comprehend.

In contrast, Hammer (1972) views risk as the sum of the possible alternative numbers of fatalities weighted by their probabilities (Hammer 1972), and Zenter (1979) defined risk simply as the total number of deaths. Both of these definitions deal with the number of casualties alone and do not touch at all on the economic, physical or social aspects of risk.

Petak and Atkisson (1982) interpret risk, conceptually, as being a function of two major factors: first, the probability that an event, or a series of events of various magnitudes, will occur, and second, the consequences of those events. This concept of the meaning of risk stems from the idea of probabilities, yet it adds a distinct difference. Consequences are the true risk makers. If there were no outcomes for actions taken (i.e. if there were not positive and negative aspects to living on a flood plain), there would be no risk factor.

Covello and Merkhfer (1993) define risk as, at minimum, a two-dimensional concept involving the possibility of an adverse outcome, and uncertainty over the occurrence, timing, or magnitude of that adverse outcome. If either attribute is absent, then there is no risk. More formally, risk is defined as a characteristic of a situation or action wherein two or more outcomes are possible, the particular outcome that will occur is unknown, and at least one of the possibilities is undesired. This definition is not standard in risk assessment texts, but it is consistent with the way people think about risk. Another problem with the definition of the term risk is the way in which it is viewed by the general public. What still remains unclear is the exact meaning of the term "risk". Is it the number of dead, the possibility that something will happen, or is it the consequences of choices made? Glickman and Gough (1993) explain that the meaning of risk has always been fraught with uncertainty. Morgan inserts the statement that, "Indeed, uncertainty is at the heart of the definition of risk" (Morgan 1993 p.33).

Ansell and Wharton (1992) state that the basic risk paradigm can be represented in the form of a decision tree (See Figure 3). A decision problem in which there is a choice between just two options, one of which will have only one possible outcome whilst the other option has two possible outcomes. The first option leads to a certain outcome (this is often the no change or status quo option), and the other has two probabilistic outcomes, one being a gain and the other a loss.

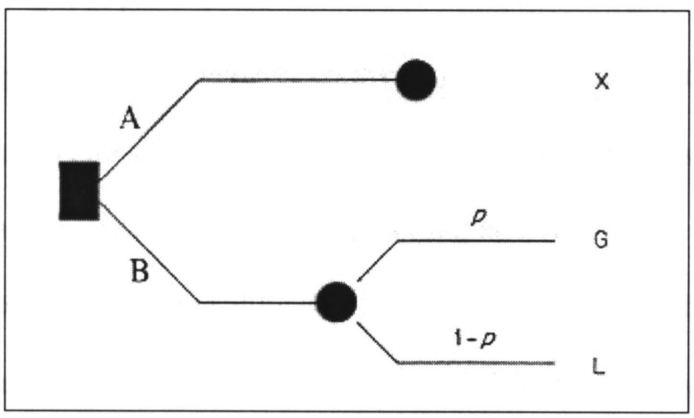

Fig. 3: The basic risk paradigm.
(Source: Adapted from Ansell and Wharton, 1992)

Risk as defined by Crozier, in *The Terminology of 'Natural Hazard' Assessment*, is the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk (Crozier 1988). He goes on to state that risk is only a symptom of hazard and that part of the problem of misunderstanding results from the large number of different disciplines active in the field of natural hazard research. This definition of risk seems to be the most comprehensive examined thus far. It touches ground on the physical, economic and structural aspects of the impacted society.

Vulnerability - An Ever Changing Paradigm

In addition to risk it is also important to understand the elements of vulnerability. UNDRO defines vulnerability as the susceptibility to damage or injury (UNDRO, 1982). Taken literally this terminology leads one to believe that vulnerability is the possibility of being damaged or injured. As discussed earlier, the possibility, or probability, of something happening is in part a definition of risk. Thus, according to this definition, risk = vulnerability. In fact, the literature on disasters suffers from a certain degree of confusion between the terms 'risk' and 'vulnerability'. The two terms are not synonymous, but rather are two sides of an ever changing issue.

The Terminology of 'Natural Hazard' Assessment, by Crozier (1988), states that vulnerability is the degree of loss to a given element at risk or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss). Similarly, Alexander (1997) states that vulnerability is defined as a measure of loss and as a measure of exposure to a loss. These definitions place vulnerability and risk on the same side of one coin. Risk was defined as the expected number of lives lost, persons injured, damage to property and so forth. These definitions propose that vulnerability is the actual number of losses, and that vulnerability is a measure of exposure to a loss. This assertion states that vulnerable persons are exposed to loss, when in all actuality vulnerable persons are those who have more of a chance to be exposed to loss and less of a chance to recuperate from that loss.

There are some, however, that present a more refined understanding of the concept of vulnerability. Cutter (1994) and Panizza (1991) both think of vulnerability in terms of the degree to which a system, including population, buildings, infrastructures, economic activity, social organization and any expansion and development programs in an area may react adversely to the occurrence of a hazardous event. Cutter adds that vulnerability is also the measure of a system's capacity to absorb and recover from the occurrence of a hazardous event. This definition of vulnerability shows a move toward an approach based on the social, cultural and economic roots of a society. It declares that vulnerability is intricately weaved into our lives through outside forces that until now have not been considered.

Along these same lines, Smith (1996) states that the concept of vulnerability implies a measure of risk combined with the level of social and economic ability to cope with the resulting event. The idea of "resilience to hazard" surfaces within this explanation of the term vulnerability. Smith infers that a community that has less capacity to cope with a disaster is more vulnerable to that disaster. This position reveals that vulnerability is not all about time and place, but that a multi-disciplined approach must be taken in order to truly identify vulnerable persons.

Still others view vulnerability as a state of defenselessness which renders a community powerless to withstand the debilitating effects of events commonly perceived as disaster or natural hazards (Mustafa 1998). This state of defenselessness and insecurity may cause a person to suffer shocks and stress when exposed to a hazard and is symptomatic of deprivation (Figure 4). Mustafa then states that poverty is one of the most important dimensions of that deprivation, along with others, such as physical weakness, isolation, and powerlessness. Overall, vulnerability to hazard is caused by lack of resilience against environmental stress. This resilience is a function of access to productive resources, education, and political empowerment (Mustafa, 1998). Without proper access to these resources one usually becomes more vulnerable than they otherwise would.

In a similar way, Susman *et al.* (1983) state that 'vulnerability is the degree to which different classes in society are differentially at risk, both in terms of the probability of occurrence of an extreme physical event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover. As discussed above, a community or an individual becomes more vulnerable if it is unable to recover from catastrophe. Individuals and communities that do not have the proper resources to facilitate a complete return to normalcy automatically become more vulnerable to an event of the same, or more often of less intensity.

The same is thought by Hewitt (1997), who refers to vulnerability as the attributes of persons, or activities and aspects of a community that can serve to increase damage from given dangers. Much of human vulnerability arises, or is decided, with little or no regard to particular hazards (see Figure 5). Human vulnerability may depend on social characteristics such as age, gender and health status, and how society treats its members or different groups. Vulnerability also depends upon the quality and siting of buildings and land uses, public infrastructure and services, and ways of life and political authority.

PROGRESSION OF VULNERABILITY

Root Causes/	Mechanisms	Dynamic Pressures	Unsafe Conditions	Flood Hazard
Entitlement •Unequal asset ownership and income	Exchange relations in cash economy	**Class** •Low income means precarious livelihood, easily disreputable •Fewer assets mean less ability to recover **Gender** •Women more likely to be a liability during a disaster because of their limited mobility and education	**State Negligence** •Reduced productivity from water logging & salinity problem •Levees on spillways and rivers poorly maintained •Allowing people to live in known hazard area and not providing alternate land despite requests by the locals	**Climate Change** •Predictions of greater flood frequency and intensity **Environmental Degradation** •Especially in Himalayan watersheds of the five rivers
Empowerment •Patriarchy •Political power structure that favors the large landlord •Cosmetic enfranchisement	•Demographic growth •Poverty and lack of social welfare •Lack of Political rights	**Age** •Children and old more susceptible to disease **Political Impotency** •People in the flood plain have to stay in its management	**Resilience** •Loss of livelihood during floods leading to indebtedness and reduction in assets •Small farmers dependent on income from land particularly vulnerable to likely destruction of valuable cash crops & investment in them	**Human Errors** •In the mainly human managed hydrologic system like the Indus, human error can be a cause of major disasters e.g., the opening of Mangla dam gates in 1992 letting out one million ft3/sec of water to cause the biggest flood in Pakistan's history
Political Economy •Demand for foreign exchange driven by the elite •The equation between economic & political power	•Economic compulsions to grow cash crops	**State Policy** •Urban development bias leaves the rural areas unprotected and poor •State creates risk by its management of the irrigation system	**Health** •Existing poor health conditions raise risk of infection •Virtually non-existent health facilities within a reasonable distance	

Fig.4: The Progression of Vulerability. (Source: Adapted from Mustafa, 1998).

1. *Exposure* (location, proximity) to dangerous agents and environments.
2. *Weakness*: predisposition of persons (dependent populations), buildings, communities or activities to greater harm them.
3. *Lack of protection* against dangerous agents and for weaker persons and items (housing structure type).
4. *Disadvantage*: lack of the resources and attributes to affect risks or respond to danger.
5. *Lack of resilience*: limited or no capacity to avoid (mobility), withstand, or offset (economically) and recover form disaster.
6. *Powerlessness*: inability to influence (through social networks) safety conditions, or acquire means of protection and relief.

Fig. 5: Some basic forms in which vulnerability arises.
(Source: Adapted from Hewitt, 1997)

Tobin and Montz (1997) adopt a systems approach, defining vulnerability as a combination of the physical characteristics of natural hazards, political/economic factors, and social characteristics. This approach suggests that if we alter one of the elements, we have altered vulnerability. They also state that vulnerability represents a combination of risk and response. These relationships are shown in Figure 6.

At a broad scale, factors that govern the increasing vulnerability of countries to hazards, urbanization, industrialization and technology often make the local residents more vulnerable overall. Population pressures, poverty and gender relations influence vulnerability by making certain segments of the population more susceptible to the impacts of disasters once they occur (Cutter 1996).

Blaikie *et al.* (1994) state that vulnerability refers to social and material conditions derived from characteristics of individuals and groups that make them susceptible to

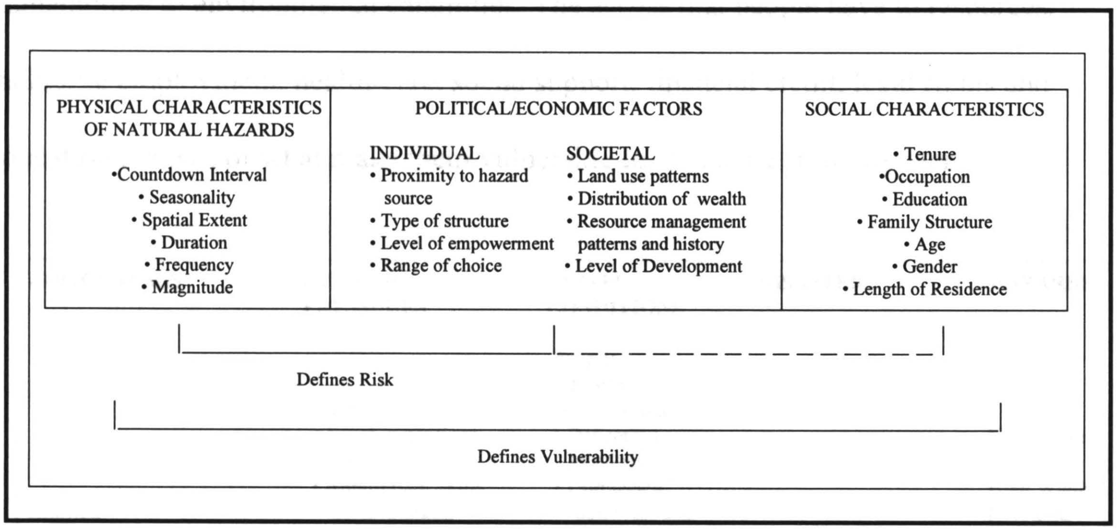

Fig. 6: Elements of Risk and Vulnerability.
(Source: Adapted from Tobin and Montz 1997)

harm and loss from environmental hazards and that constrain their ability to cope with the adversities of disasters. Tobin and Montz (1997), Hewitt (1997) and Mustafa (1998), make it clear that the most vulnerable are those households with the fewest choices; those whose lives are constrained, for example, by poverty, gender oppression, ethnic discrimination, political powerlessness, physical disabilities, limited employment opportunities, the absence of legal rights and other forms of domination, as shown in Figure 7. Blaikie *et al.*, however, provide clear leadership when it comes to definitions of vulnerability. They look more deeply into the human, cultural and structural aspects of the natural hazards issue in order to advance a clearer image of vulnerability.

Many influential writers have seen vulnerability as one of the keys to understanding disaster, because it is correlated with the underprivileged, with past losses and with susceptibility to future losses (Blaikie *et al.* 1994). Social inequities along the lines of class, race, ethnicity, gender, age and national origin are key elements in people's vulnerability to environmental calamities. The access that people have to resources, including employment, health-care, social support, financial credit, legal rights and education are part of what make them vulnerable to, or secure from disaster.

ROOT CAUSES	DYNAMIC PRESSURES	UNSAFE CONDITIONS	DISASTER	HAZARDS
Limited access to • Power • Structures • Resources Ideologies • Political systems • Economic systems	**Lack of** • Local institutions • Training • Appropriate Skills • Local markets • Press freedom • Ethical standards in public life **Macro-forces** • Rapid population growth • Rapid urbanization • Arms expenditure • Debt repayment schedules • Deforestation • Decline in soil	**Fragile physical environment** • Dangerous locations • Uprotected buildings and infrastructure **Fragile local economy** • Livelihoods at risk • Low income levels **Vulnerable Society** • Special groups at risk • Lack of institutions **Public actions** • Lack of disaster preparedness • Prevalence of endemic disease	RISK = Hazard + Vulnerability **R = H + V**	Earthquake High Winds (clyclone/ hurricane/ typhoon) Flooding Volcanic eruption Landslides Drought Virus and pests

Fig. 7: Pressure-Release Model.
Source: Adapted from Blaikie *et al.*, 1994, p. 23

Risk Assessment and Analysis

Hertz and Thomas (1984) and Singleton and Hovden (1987), state that probability is a basic notion in the evaluation of risk. It is not synonymous with risk, as risk is usually defined to be some function of probabilities and consequences. They all attempt to define risk analysis as a method which aims to develop a comprehensive understanding and awareness of the risk associated with a particular variable of interest. This simplified explanation of risk analysis serves the purpose to which it is proposed well. The reason behind the analysis is, in fact, to develop an understanding and awareness of hazard potentiality for a given location. Singleton and Hovden (1987) express further that in order to solve problems involving uncertainties and random variations, mathematical concepts from the theory of probability and mathematical statistics are employed. The basic ingredients in the mathematical model for probability are the sample space, the events, and the probability functions. For example, the smaller the study area and the smaller the event, the less probability that area has to be impacted, or conversely with a large study area and large event, the probability of occurrence or impact is greatly widened.

Hewitt (1997) takes a different approach to the definition of risk assessment by suggesting that there is a struggle between a narrow, essentially quantitative technical view of risk and a broad social and cultural one. The narrow view seeks to estimate the probability of a certain outcome in a specific system or population. However, the damaging events and human losses that concern us most are primarily threats beyond, or that break out of, technical and institutional frameworks. This view asserts that there is more involved in the process of risk assessment than merely probabilities of disaster occurrence. The analysis of risk is indeed a combination of social, cultural, economic and physical processes.

Risk analysis is described by Morgan (1993) as a process which starts with analysts dividing hazards into two parts: exposure and effect. Exposure studies look at the ways in which a person (or, say, an ecosystem or a piece of art) might be subjected to change; effects studies examine what may happen once that exposure has manifested itself (Morgan 1993). This interpretation of risk analysis begins to look at the larger picture of hazards and attempts to take into account the many different ways that a person might be affected by a hazard. Following along the same lines as Morgan, Garrick and Gekler (1991) state that risk assessment is a process which evaluates the collective demographic, geographic, physical, chemical, and biological factors at a site to determine whether or not there may be risk to public health or the environment.

Burby (1998) views risk assessment as a concept that incorporates estimates of the probability of various levels of injury and damage to provide a more complete description of the risk from the full range of possible hazard events in the area. He believes that risk analysis is the most sophisticated level of hazard assessment because it involves making quantitative estimates of the damage, injuries, and cost likely to be experienced within a specified geographic area over a specific period of time.

Others, such as Petak and Atkison (1982), Russell *et al.* (1987), and Covello and Merkhoffer (1993) take defining risk assessment to this next level of sophistication. They all define risk assessment as: 1.) A systematic approach, or structured analysis, for describing and quantifying the risks associated with hazardous substances, processes, action, or events; 2.) Any self-contained systematic procedure conducted as part of a risk assessment; 3.) Any procedure that can help generate a probability distribution for health or environmental consequences; and 4.) A component of risk analysis, which consists of three stages: i) hazard identification, ii) risk assessment, iii) risk evaluation. All three definitions of risk assessment conclude with a statement which infers that appropriate evaluation of a hazard requires a determination of the probability of the occurrence of a natural event at its various intensity levels. Figure 8 depicts the relationships between the three stages of risk analysis and how they relate to risk management.

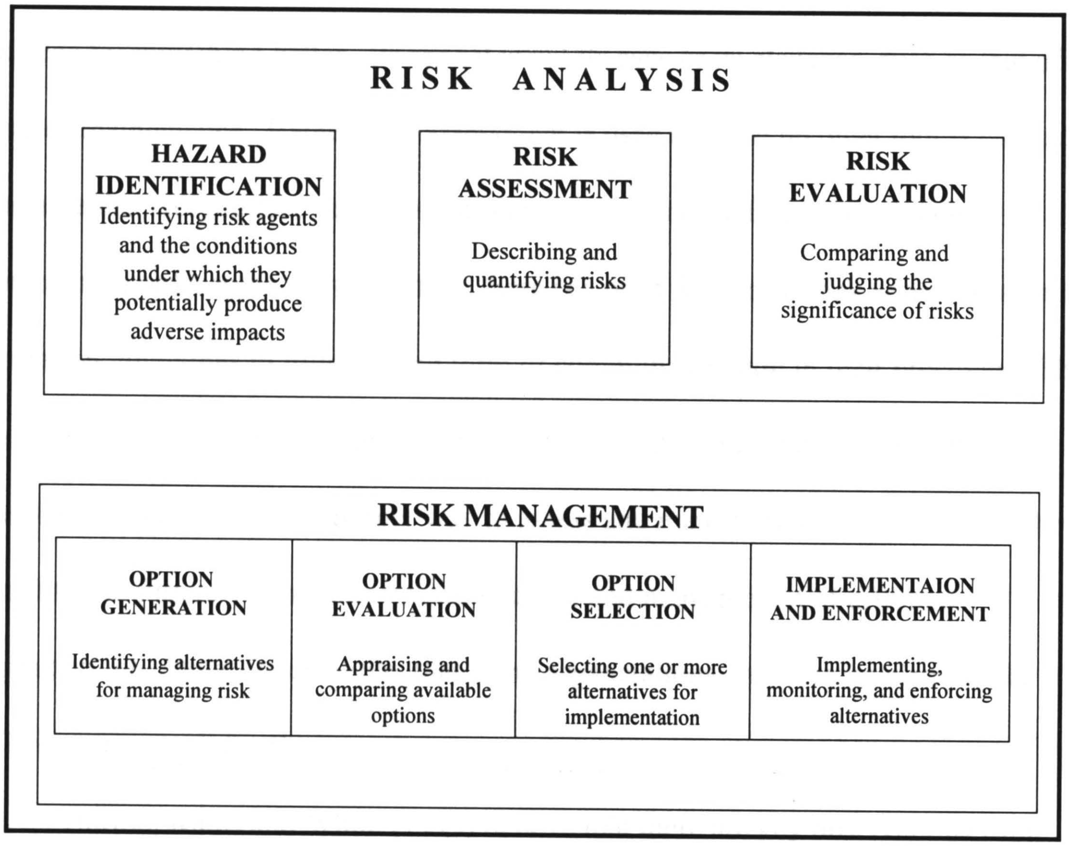

Fig. 8: The three stages of risk analysis-hazard identification, risk assessment, and risk evaluation. (Source: Adapted from Covello and Merkhoffer, 1993)

Panizza (1991), follows the same line of thought by stating that environmental risk is defined as the probability that the economic and social consequences of a particular hazard phenomena will exceed a determined threshold. Therefore, environmental risk is equal to the product of the environmental hazards multiplied by the vulnerability of an area. Environmental risk assessment must therefore include the stage consisting of the analysis of the interrelations existing between the various forms of possible hazards within an area.

Yet problems still arise with any use of risk assessment. As stated by Lave (1982, 12), "The difficulties of quantitative risk assessment may qualify the results, but they do not preclude its use. Whatever the difficulties, risk assessment must be used until it is replaced by something better. Its appeal is not its ease or its elegance, such as that of abstract mathematics. Rather, risk assessment is used because no other tool is currently available that can produce the information necessary for intelligent regulation". However, in order to be truly effective, there is a need for current risk assessment and regulation guidelines to follow some form of common structure in their processes. There has been too much miscommunication among the many organizations and entities deciding for themselves the proper way to assess and manage risks that order must be established. Figure 9 compares risk assessment and management of different organizations. Note, for example, that some organizations are more involved in the different process than others.

Burton, Kates and White (1993) believe that there are key observations from natural hazards research that are important to risk assessors. These include the ideas that hazards have natural and technological aspects which vary from place to place. For example, tornadoes, which occur in many locations throughout the United States, affect areas differently because of meteorological conditions as well as differences in development policies. The analysis of risk needs to take into account the perception of the affected people. It is believed that people will become more at risk to a hazard if they are unaware of the consequences that accompany the hazard. Thus, risk analysis includes the social structures of societies. One must look at the whole picture when defining risk as it is often a product of more than just the hazard event at a certain place. People may be more at risk if they do not have access to certain social needs.

Risk communication is also important as it differs by the nature of the message. Risk advisories should be clear and understandable to ensure that all persons hearing the message realize the level of risk. Finally, cost-benefit analysis has severe limitations and may often be misleading. Hazards may be more devastating in some areas even though the cost benefit analysis shows differently. For example a category II hurricane in Florida might cause more monetary damage than it would on a Caribbean island, but that island might have complete devastation because of inadequate development protocols prior to the event. The above seem fair observations of the use of risk assessment from a theoretical perspective, yet these authors do not give an opinion along the lines of how, in a practical fashion, one is to deal with these problems.

SCOPE (1980)	NRC/EPA (1983/1984)	ROYAL SOCIETY (1983)	ICTC (1984)	WHO (1985)
RISK IDENTIFICATION	RESEARCH HAZARD IDENTIFICATION	RISK ESTIMATION	HAZARD IDENTIFICATION	HAZARD IDENTIFICATION
RISK ESTIMATION	DOSE-RESPONSE ASSESSMENT EXPOSURE ASSESSMENT RISK CHARACTERIZATION	RISK ESTIMATION	RISK ESTIMATION	RISK ESTIMATION
RISK EVALUATION	DEVELOPMENT OF REGULATION OPTIONS EVALUATION OF OPTIONS	RISK EVALUATION	DEVELOPMENT OF ALTERNATIVE COURSES OF ACTION DECISION ANALYSIS	RISK EVALUATION
RISK MANAGEMENT	DECISIONS AND ACTIONS	RISK MANAGEMENT	IMPLEMENTATION MONITORING AND EVALUATION REVIEW	RISK MANAGEMENT

Fig. 9: A comparison for risk assessment and risk management
(Source: Adapted from Lave 1987)

"Despite these difficulties, science has devised mechanisms for estimating, however imperfectly, the probability of rare events" (Whipple 1987, p29). The use of probabilistic risk assessment, which seeks to identify all sequences of subsystem failures that may lead to a failure of the overall system and then estimate the consequences of each identified system failure, along with a variety of empirical and theoretical approaches have been used in the analysis of environmental risk, but thus far no assessment of natural hazard risk has been covered.

"Is there any hope for a purely empirical (atheoretical) basis for estimating risk, as seems to be indicated by current practice in risk analysis? Not if science is to be invoked as a warrant, and by science one means a discipline characterized by conceptual understanding, deductive success, and confidence in the crafting of solutions" (Cothern 1993 p 276). It is obvious that there is no clear cut or generalized answer to the question of 'how safe is safe enough," or even to the issue of when environmental risk becomes perceived and recognized as potential environmental hazard (Palm 1990, 26). Explicit risk analyses are a fairly new addition to the repertoire of intellectual enterprises. As a result, the experts are only beginning to reach consensus on terminology and methodology. "Their communications to the public are only beginning to express some coherent perspective and to help the public sort out the variety of meanings that 'risk' could have." (Covello *et al.* 1983, 277). This is to be the understanding of risk assessment thus far. There is no truly perfect, quantitative, all-encompassing method of deriving risk. It is only through research and revision that an acceptable estimation of risk at a specific area can be determined. However, it will be through an interdisciplinary approach to hazards that those most at risk will be identified. Montz (1994), provides an excellent analysis of risk in her paper; *A Methodology for Analysis of Multiple Hazard Probabilities: An Application in Rotorua, New Zealand*. This document states that, it is important to evaluate vulnerability to loss, a factor that will vary depending upon a number of factors, including where, when, and how severe an event is experienced (Montz 1994). Her research shows that one must incorporate these elements into the analysis of composite vulnerability to multiple hazards in order to provide a more comprehensive methodology for evaluating the nature and extent of the problem. The report recognizes that a difficulty arises in analyzing the results because different geophysical events affect smaller or larger areas and because of different levels of development and vulnerability that exist throughout the community (Montz 1994). A shift in thought is seen in this document that has not been previously suggested elsewhere. The idea that different people have different vulnerabilities to a disaster of the same magnitude comes across in this literature. It is this difference in vulnerability that will enable us to promote resilience and foster a more precise understanding of what in fact makes people vulnerable to hazard. Montz has taken a step into an uncharted world with the statement that most hazards research deals with one hazard or event at a place. Her work on multiple hazards represents an important contribution because of its recognition that a site's vulnerability may be better understood by the complex of hazards to which it is prone.

Petak and Atkisson (1982) devote a whole section to the discussion of natural hazards risk assessment and mitigation analysis. It is in this section that such things as actual hazard assessments are divulged. It is stated that the central element in the examination is the risk analysis. The major components of this analysis are shown in Figure 10. The performance of this analysis requires the development of computer based hazard, exposure, and vulnerability models, which are then used with appropriate damage algorithms and risk equations in a series of separate studies, each concerned with a specific natural hazard (Petak and Atkisson 1982, p103). These authors took the initiative to spell out the exact recipe for risk assessment including the use of work and research completed before them. Petak and Atkinson seem to have captured a useable risk assessment technique.

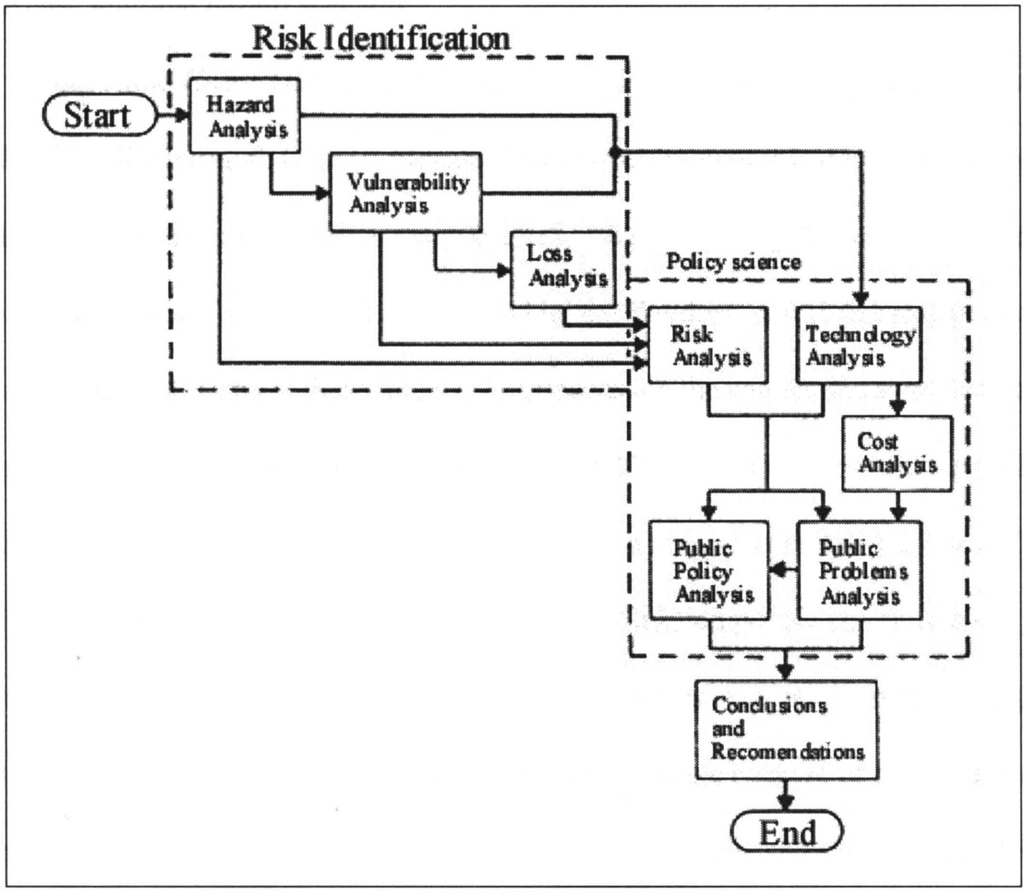

Fig. 10: The major components of risk analysis.
(Source: Revised from Petak and Atkisson, 1982)

Hazards Identified

There are many natural hazards that could potentially affect Florida, including threat of hurricane force winds, rain and storm surge, tornadoes, sinkholes, flooding, lightning, freeze, drought, wildfire and hail. This study looks specifically at the hurricane hazard, tornado hazard, sinkhole hazard and flood hazard in order to determine a potential worse case multiple hazard scenario.

Hurricane Hazard is seen as potentially the single most devastating event that could affect Hillsborough County, Florida. Because of its subtropical location and long coastlines, Florida is particularly susceptible to hurricanes. The greatest threats posed by a hurricane are storm surge, wind damage and inland flooding, and Hillsborough County is susceptible to all three of these threats. Hurricanes are the natural disasters that pose the greatest threat to Hillsborough County. "About 405 million of the world's population live in zones where hurricanes may be expected with a return interval of 1-25 years" (White and Haas 1975, 244). In Florida, more than 6 million people currently are exposed to the storm surge hazard. Hillsborough County is susceptible to storm surge, wind damage, and inland flooding resulting from a hurricane because of its location on Tampa Bay and the Gulf of Mexico. The Saffir-Simpson scale, shown in Figure 11 is used to delineate the intensities and damage for the different categories of storm events. Between 1886 and 1979 Hillsborough County experienced the effects of 34 hurricanes which passed within 100 nautical miles of the county. This represents a frequency of one hurricane every 2.8 years, or approximately a 1-in-3 yearly chance of occurrence. Thus, all of Hillsborough County is at risk of hurricane damage, but to different extents. Locational probabilities can be computed for Hillsborough County based on storm surge,

Storm Classification	Maximum Wind Speed (knots-mph- km/h)	Minimum Pressure (kPa-inches Hg)	m Surge (meters-feet)	Effects
Tropical Storm	34-63 39-73 61-117	Not Applicable	Not Applicable	**Minimal**
Category 1: Hurricane/ Typhoon	64-82 74-95 118-153	> 98.0 > 28.94	1.0 - 1.7 4 - 5	No real damage to buildings. Damage primarily to unanchored mobile homes, shrubbery, trees. Some coastal road flooding, minor pier damage.
Category 2: Major Hurricane/ Typhoon	-95 96-110 154-177	96.5 - 97.9 28.50-28.91	1.8 - 2.6 6 - 8	Some roofing material, door, and window damage to buildings. Considerable damage to vegetation, mobile homes, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of center. Small craft in unprotected anchorages break moorings.
Category 3: Major Hurricane/ Typhoon	96-113 111-130 178-209	94.5-96.4 27.91-28.47	2.7 - 3.8 9 - 12	Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain continuously lower than 5 feet ASL may be flooded inland 8 miles or more.
Category 4: Major Hurricane/ Typhoon	114-135 131-155 210-248	92.0 - 94.4 27.17-27.88	3.9 - 5.6 13 - 18	More extensive curtain wall failures. Some complete roof structure failures on small residences. Major erosion of beach. Major damage to lower floors of structures near the shore. Terrain continuously lower than 10 ft. ASL may be flooded. Massive evacuation areas inland as far as 6 miles.
Category 5: Major Hurricane/ Super Typhoon	> 135 > 155 > 248	< 92.0 < 27.17	> 5.6 > 18	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Major damage to lower floors of all structures located less than 15 ft. ASL and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5 to 10 miles of the shoreline.

Figure 11: Saffir-Simpson Hurricane Scale. (Adapted from http://www.aoml.noaa.gov/general/lib/laescae.html, 9-17-00)

wind speed and flood potentials for given areas. For instance, hurricanes, can be given different risk potentials for different locations within Hillsborough County. Effects will be different based on the magnitude of the storm, including surge, winds and flood potential.

One must remember that the cause of the hurricane hazard, as well as numerous other natural hazards, is rooted in social conditions, actions, and policies (Elsner and Kara, 1999). A natural event only becomes a hazard when it interacts with the human environment. This fact drives the question, "What will make us less at risk, or less vulnerable to these events?" For example, research on hurricanes is concerned primarily with physical studies designed to improve prediction and test the feasibility of hurricane modification. "Future efforts must also focus on understanding the social ramifications of the hurricane hazard and encouraging more adaptive human responses" (White and Haas 1975, 249). In the case of flooding, "There is little likelihood, at the present levels of technology, that capabilities or construction costs of the larger works will change to permit a different range of social choices among possible adjustments to floods" (White and Haas 1975, 259).

Tornado hazard, although not often though of as a major threat to lives in Florida is a hazard that deserves recognition as a potential threat to Hillsborough County. Florida ranks fourth in the nation in the occurrence of tornadoes, after Texas, Oklahoma and Kansas (Hillsborough County Hazard Vulnerability Analysis, 1984). In the 29 years between 1953-1982, Florida reported 1, 285 tornadoes, which represents a yearly average of 44, and a total of 54 deaths have been linked to the violent winds associated with them (Hillsborough County Hazard Vulnerability Analysis, 1984). However, tornado related damage in Florida is generally less than the national average. "This is due to the fact that Florida's tornadoes are generally of shorter duration (3 miles) and have narrower paths (125 yards). Tornadoes in other portions of the nation are generally 14 miles long and 300 to 400 yards wide" (Hillsborough County Hazard Vulnerability Analysis, 1984, 27). The Fujita scale of tornado intensity, shown in Figure 12, describes the characteristics of the different levels of tornadoes, with intensity being calculated by analyzing damage to the single most impacted structure. Hillsborough County ranked highest in Florida in tornadoes during 1950 to 1976 with 59 tornadoes, an average of 2.1 per year, and also experienced 3 deaths during this period due to tornadoes. The county had 33 tornadoes touch down during 1975 to 1983, an average of 3.6 per year. Because Hillsborough County has experienced at least 1 tornado each year since 1975, except 1980, the annual probability of a tornado touching down in Hillsborough county is close to 100%. Because it is difficult to determine when a tornado will strike, where it will travel, how long it will last, and the magnitude of its winds, nothing is immune from its effects (Hillsborough County Hazard Vulnerability Analysis, 1984). Following this line of thought, the risk potential for tornadoes in Hillsborough county is all encompassing, much like the risk of lightning strike. It is therefore held that every location throughout Hillsborough County is at equal risk of being struck by a tornado.

Sinkhole hazard in Hillsborough County has been an ever increasing problem for developers and land planners. The entire state of Florida experiences sinkholes due to the formation and consistency of the underground geologic structure. The degree of water usage, amount of excessive rainfall, and the lack of rainfall also contribute to the formation of sinkholes. Hundreds of sinkholes have occurred in Hillsborough County

F-scale	Intensity phrase	Wind speed	Type of damage done
F0	Gale tornado	40 -70 mph	Some damage to chimneys; breaks off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	73-112 mph	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off road; attached garages may be destroyed
F2	Significant tornado	113-157 mph	Considerable damage. Roofs torn off frame homes; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206 mph	Roof and some walls torn off well constructed houses; trains overturned; most trees in forests uprooted.
F4	Devastating tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.
F6	Inconceivable tornado	319-379 mph	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly attributed as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

Fig. 12: Fujita scale of tornado intensity.
(Source: Adapted from http://tqjunior.thinkquest.org/4232/fujita.htm)

over the years, many of which have formed lakes. Records indicate that 241 sinkholes were reported from 1975 to 1991 (Hillsborough County Hazard Vulnerability Analysis, 1984). Although most were relatively small, some have caused minor damage to dwellings and commercial establishments. With 241 sinkholes reported in 16 years, the probability is that there will be fifteen or more per year. Yet, all of Hillsborough County is not at the same risk for sinkholes. There are some areas where sinkholes dominate the landscape and thus cause a greater risk potential. According to a 1996 geological report, the northwestern quarter and east central portion of Hillsborough County seem to be at the most risk to sinkhole hazard (Subsurface Evaluations Incorporated, 1996).

Flood hazard is the most widespread geophysical hazard in the United States. Nearly every community in the nation has some kind of flood problem, chiefly resulting from inadequate drainage systems for runoff water produced by heavy rainfall from storms. Flooding is a continuous problem for Florida as a whole. Flooding in the state can result from storm surge, riverbank overflow, or ponding. Hillsborough County is susceptible to all three of these threats.

Storm surge is caused by a large dome of water created by the extreme low pressure within the eye of a hurricane. Because of the massiveness of this dome, sometimes up to 18 feet above normal sea level, its potential for destruction near the coastline is quite high. Flooding resulting from riverbank overflow, on the other hand, is almost always caused by heavy rains within a drainage area and the subsequent inability of the river to accommodate the additional runoff. Riverbank overflow, as it relates to Hillsborough County, occurs following an extended period of rainfall, causing most bodies of water in the county (the Alafia, Hillsborough and Little Manatee river, Rocky

Creek, and several smaller creeks and branches) to flood. This causes different areas to be affected in disparate ways, thus giving a differential risk potential to all areas of Hillsborough County. In addition, flood mitigation measures can reduce the probability of flooding. Ponding occurs in low lying areas that are characterized by either poorly drained or super saturated soils. This type of flooding is a problem in Hillsborough County, particularly in the northwestern and southwestern portions of the county where relief is low and wetlands dominate the landscape. Ponding would also cause differential risk potentials throughout Hillsborough County.

Vulnerability Assessment

It is clear to most involved in the assessment of vulnerability that natural and related technological disasters are not problems that can be solved in isolation, but symptoms of more basic problems culturally created and based on the ways in which we view the natural world. "It is thus concluded that it is time for a change in the prevailing thinking about how we cope with these hazards" (Mileti 1997, p1).

Cutter (1994) states that the goal of vulnerability assessment is to find practical ways of defining who is most vulnerable to global change and why. She asserts, for instance, that the most vulnerable people may not be in the most vulnerable places- poor people can live in productive biophysical environments and be vulnerable, and wealthy people can live in fragile physical environments and live relatively well.

David Alexander (1991) has proposed an approach to vulnerability assessment based on simple conceptual equations and that vulnerability has a clearly identifiable locational dimension where people marginalized by class, politics or ethnicity are driven to the hazardous peripheries of place. This illustrates the fact that overall vulnerability can be broken down into many component parts based on different aspects of the problem. Bolin and Stenford (1998) follow this line of thinking by asserting that, vulnerability analysis shows that the problems people experience in disasters are frequently traceable to already-existing constraints on their access to resources and livelihoods (Bolin and Stenford 1998). Yet complications still remain in the explanation of vulnerability assessment and changes in vulnerability. Tobin and Montz (1997) believe that measuring the extent to which vulnerability has been altered is a difficult undertaking, but certainly one that should be incorporated into any development plan as well as in hazard mitigation planning and disaster relief programs. This statement speaks volumes when it comes to vulnerability assessment. The assessment of vulnerability is problematic in that much research is needed in order for it to become a usable tool for mitigation strategies, public policy and community awareness.

In *Cooperating with Nature*, Burby (1998), states that vulnerability assessment combines the information from hazard identification with an inventory of the existing property and population exposed to a hazard. It provides information on who and what are vulnerable to a natural hazard within the geographic areas defined by hazard identification. Vulnerability assessment can also estimate damage and casualties that will result from various intensities of the hazard. Assessments attempt to predict how different types of property and population groups will be affected by a hazard. Vulnerability functions are empirically derived relationships that describe the response of populations, structures, or facilities to a range of hazard intensities. Vulnerability assessments characterize the exposed populations and property and the extent of injury and damage that may result from a natural hazard event of a given intensity in a given area. This concept of assessing vulnerability seems the most comprehensive and effective thus far. It uses information from hazard magnitude along with data of those affected by the event in order to attempt a picture of vulnerable populations. Nevertheless, this framework has not been applied to vulnerability assessments to date.

There have been other advances in the area of vulnerability assessment at the community level. For example, Longhurst (1995 p 269) points out that, "As part of its International Decade for Natural Disaster Reduction (IDNDR) activities, the Implementation and Applications Working Group of the UK National Coordination Committee, organized a meeting on a topic that is exercising many professionals at the moment: Community Vulnerability Assessment (CVA), The primary objective of the workshop was to promote the development of appropriate response tools and techniques to measure and analyze human vulnerability. Secondary objectives were to promote inter- and multidisciplinary networking, and between diverse hazard communities, highlight the importance of CVA as a component of risk assessment and identify research gaps and indicate how they might be filled.

Social Characteristics of Vulnerability

A general lack of consensus on the explanations, factors, measures of vulnerability, and spotty, largely uncoordinated, and physical based research in academic and policy circles significantly impedes real progress in various policy arenas (Dow 1992, White and Haas 1975). Since there is little consistency in the definitions of vulnerability, one would expect it to be quite difficult to operationalize the concept of using specific variables or indicators (Cutter 1996). The following review depicts the wide range of definitions and concepts revolving around vulnerability as it applies to natural hazards:

Kasperson *et al*., in 1995, proposed that vulnerability is a product of three dimensions: exposure, resistance (the ability to withstand impacts), and resilience (the ability to maintain basic structures and to recover from losses) (Kasperson *et al*. 1995). Others, such as Cutter (1996), White and Haas (1975), Cannon (1994), Downing (1991), Liverman (1990), and Par (1987) delve deeper to attempt to explain these three dimensions. Rarely mentioned however, are the underlying causes of increased social vulnerability to hazards or disaster events. Yet, vulnerability now forms the cornerstone of international efforts aimed at reversing the downward spiral of poverty, population increase, development and environmental degradation (Cutter 1996). This major approach to hazard research, known as the social vulnerability paradigm, has looked at the way in which a variety of socioeconomic factors affects the vulnerability of populations to hazards and disasters over time. In the United States, the key characteristics that seem to influence disaster vulnerability most are socioeconomic status, gender, and race or ethnicity. In the extent of disasters, special needs populations (elderly, disabled, lactating women, children under 5) are identified as among the most vulnerable (Parr, 1987). Differences in these factors result in a complicated system of stratification of wealth, power and status. This stratification results in differential decision making and perception of hazards, diverse types of mitigation techniques, an uneven distribution of exposure and vulnerability to hazards, disaster losses and other impacts and access to aid, recovery and reconstruction. (Cannon 1994, Downing 1991, Liverman 1990). White and Haas, 1975, attempt to explain vulnerability characteristics as follows:

> "The nations vulnerability to natural hazards in being increased by the following factors. 1. Shifts in population from country and city to suburban and exurban locations. More and more people live in unprotected flood plains, seismic risk areas and exposed coastal regions. 2. More people live in new and unfamiliar environments where they are totally unaware of potential risks and the possible ways of dealing with them. 3. The increasing size of corporations enlarges their capacity to absorb risks, which may result in plants being located in high risk areas, or failure to adopt hazard resistant building methods. The location of these firms attracts job-seekers and housing development to the same dangerous locations. 4. The rapid enlargement of the proportion of new housing starts accounted for by mobile homes means more families are living in dwellings which are easily damaged by natural hazards"
> (White and Haas 1975, 245)

Note that in many instances, gender, race and ethnicity are not the key factors in increased exposure or vulnerability but rather are indicators of lower economic status and a relative lack of power. Hazard risk is primarily based on location, whereas, vulnerability to that same hazard is based on social characteristics such as income, gender, age, type of and density of housing, and population. The influence that these characteristics have on human vulnerability to hazards will be discussed further here:

Median house value can be seen as an influential factor in the area of vulnerability assessment. One of the fundamental causes of human vulnerability is a lack of access to resources (Blaike *et al.* 1994). Millions of people are potentially facing environmental changes with sparse resources to reallocate or spare (Dow 1992). Although poverty is sometimes wrongly taken as synonymous with vulnerability, it does serve as a rough indicator of the ability to cope with additional stress (Dow 1992). Research finds that the poor are at greater risk to disasters, both natural and man-made, and suffer disproportionately (Fothergill 1996). In general, those with plentiful financial or other resources- such as education- are better equipped to deal with the effects of a disaster than are those with limited resources (Uitto1998). A measure of the income of a population group demonstrates the population's ability to provide for its material needs (Maloney, 1973). As income declines, the population is less able to acquire those goods which optimally satisfy needs. Proportionally greater amounts of income are then required for the provision of those essential material needs thus leaving little, if any, savings or income for other essentials. Inadequate income also decreases the population's ability to purchase protective or therapeutic professional services such as legal advise and medical care (Maloney, 1973). Thus, the poor are more susceptible to certain hazards because of a lack of resources, poor quality housing, and the inability to recover quickly (Burton, Kates, and White 1993).

Research also shows that people of lower economic status have the most trouble reconstructing their lives and reestablishing permanent housing after disasters in the United States. They have less insurance, more financial stress, more trouble negotiating bureaucracies, less access to resources, and more difficulty obtaining loans. The poor are at greater risk from natural and technological disasters in the United States and worldwide mainly because they live in lower-quality housing that is more likely to become damaged and is sometimes closer to technologically hazardous sites. On the other hand, households with higher income rates will have the ability to recover rapidly from hazard events even though they may experience greater initial economic loss

(Cutter *et al.* 1999). Affluent people are also more likely to insure themselves against damages such as those associated with natural hazards.

Income, or in the case of this study, mean house value, is thought to be inversely related to vulnerability. As income increases so does the ability to deal with hazards before during and after the actual event. Median house value is used in this study as a measure of economic level as it roughly indicates available income.

Gender can often be seen as an indicator of a more vulnerable population due to lack of resources and differential exposures (Fothergill 1996). Globally and in the United States, women are usually more vulnerable to disasters than men. Often this is due to the fact that women are generally disproportionately poor and that they are frequently influenced by their roles: they are more likely to remain with family members in emergencies to nurture, assist and protect them (Fothergill 1996, Glass *et al.* 1980). A lack of mobility and social isolation can also augment women's risk exposure and vulnerability (League of the Red Cross and Red Crescent Societies 1991, Schroeder 1987). Women often fare poorly in the reconstruction phase. They normally have less insurance, fewer savings, and thus less likelihood of a full, long-term recovery and thus have a more difficult time returning their lives to normal (Bolin and Bolton 1986).

Age acts as a factor of vulnerability in that older people often have fewer social lifelines and choices in hazard events. Frequently, older people have less mobility and poorer health than younger people. The elderly are more prone to deleterious conditions (Dershem and Gzirishvili 1998). In addition, while some persons of all ages are ill, the percentage is much higher among the aged. Often because of lack of mobility, older persons are less likely to receive warning and are more reluctant to evacuate. Often, retired people move to hazardous areas because of their climate and weather. For example, the population of the most hazardous zones typically has a large proportion of people in the over-64 age group, particularly in the coastal counties of Florida; is highly urbanized; and relies increasingly upon the use of mobile homes (White and Haas 244). In addition to older people, dependents under the age of 17 are seen as increasingly vulnerable. This mainly stems from a general lack of mobility, resources, and social and political lifelines. Young people have to depend primarily on guardians for food, shelter, and health concerns. This dependency issue leaves young people at a disadvantage as they normally have no means to protect themselves personally from injury or death should they be impacted by a hazard.

Population Density can be used as an indicator of more vulnerable populations. Disasters over the past 20 years have cost the United States more than $500 billion and the toll is rising because of an increasingly complex society and more people moving to disaster prone areas. (Associated Press 1999). “As areas become more densely populated, they also become more exposed to hazards” (Mileti 1999, 119). As population continues to expand and as resources continue to be controlled by a minor part of the population, the real standard of living drops for much of the world’s population. This population is increasingly vulnerable to environmental variation as the process continues (O’Keefe, Westgate and Wisner 1976). Of greater importance to disaster exposure is how the population is dispersed on the land. Almost half of the worlds 6.2 billion people are found to live in urban areas at the beginning of the year 2000, by 2150 the figure is expected to reach 80 percent (Mileti 1999, 120). This rapid urbanization will cause an increase in the localized population density, heightening the probability that even a small scale disaster will affect large numbers of people. Coastal areas are exposed to an assortment of natural hazards related to wind and flooding. In the United States nearly 69 million people live within 100 miles of a coast, and permanent population of hurricane prone coastal counties of the United States continues to grow at a rapid rate (Mustow 1999).

> "These demographic trends will alter exposure and vulnerability to hazards by increasing the number of households at risk for major disasters, increasing the impact of geographically small-scale events; increasing population dislocation after disasters; increasing the necessity for cooperation among contiguous incorporated areas after future disasters; resulting in fewer "local disaster experienced" people in high risk communities; and resulting in less reliance on kinship and other personal networks for aid in times of disaster and greater need for an increased governmental response" (Mileti 1999, 121).

As stated above, the number of people who will be unable to cope with a disaster event before it strikes, during the event itself and during reconstruction afterwards will increase as the population in an area increases. Demand for goods, space, and housing often overrides the need for proper evacuation roots and "safe" areas during a hazard event. Therefore, higher population is believed to be a sign of greater vulnerability.

Housing Type, the number of mobile homes in an area, indicates a greater vulnerability to hazard events. The vulnerability of low-income dwellings, in terms of both construction and location, has long been recognized as a major factor of vulnerability (Dow 1992). Poorly constructed housing, namely mobile homes and squatter settlements, or homes that are not properly built to code increase the likelihood of damage or destruction in a hazard event. For example, mobile homes, often occupied by lower socioeconomic groups, are the most dangerous housing types in tornadoes.

Building types and contents are central in economic measures of differential vulnerability (Petak and Atkisson, 1982). Those who live in mobile homes, for example, are much more likely to die in a tornado than those who live in sturdier, more expensive housing (Fothergill 1996). Homes constructed of concrete block or wood are more structurally sound than those constructed of prefabricated material. A higher number of mobile homes in an area, therefore, indicates a higher level of vulnerability than an area with more concrete block or wood frame homes.

Housing Density, in other words housing development, has increased United States vulnerability to major natural disasters (Associated Press 1999.) The number of houses in any given area will affect the way in which the natural environment is able to rebound from hazard events. Even small scale hazards can become overwhelming if the environment is not able to be naturally resilient because of increased housing development or other land use changes. Often, the pace of city growth outstrips the resources of city governments to provide basic services, let alone ensure that buildings are constructed to disaster-resistant levels (Mustow 1999). Thus, housing density is found to be positively related to natural hazard vulnerability. Flooding increases when natural drainage is impeded by changes in land use, evacuation routes become more congested with increased development and often building codes become less strict with increased development.

Renter Occupancy, or people who reside in rented homes or apartments are seen as more vulnerable for a number of reasons. Most renters do not take insurance out on their property. "According to a recent survey, three quarters of the nation's roughly 35 million renters have no insurance to protect their possessions" (Moore 1990, 70). This lack of insurance severely impairs the ability for renters to be resilient after a natural hazard event. Without insurance people have to start from the bottom rung on an economic ladder that is very difficult to climb. According to the 1990 United States Census, "one family in ten paid over half its income for housing costs. Sixty percent of these people were renters" (United States Census 1990). Renters, in addition to a lack of insurance for the most part, normally do not have capital in reserve for emergencies. Homeowners, on the other hand, often are obligated to have insurance and thus have less vulnerability. Household assets, such as owning land and home, represent physical capital that can be used to reduce vulnerability (Dershem and Gzirishvili 1998). It is therefore considered that renter occupied housing, and thus renters, have a greater vulnerability to natural disasters.

Vulnerability Analysis

Numerous studies were reviewed in order to understand the current state of social vulnerability analysis as it applies to natural hazards. Four studies completed by: The State of Wyoming (1977); The State of North Dakota (1977); The State of Washington (1996) and Kitsap County, Washington (1998) have been identified, but they all lack a proper methodology for assessment of multiple hazard vulnerability (These are examined below). In addition, numerous studies were found to be of particular relevance to the issue of vulnerability to natural hazards. The first, *Social Vulnerability in Indianapolis* (1973) almost seems to be out of place in relation to the literature of the time. This study coupled with the more recent, *A GIS-Based Hazards Assessment for Georgetown County,* *South Carolina* (1997) provide a good base for defining and analyzing vulnerability on a community level.

The Wyoming Disaster Preparedness Program's Hazard Vulnerability Analysis, undertaken in 1977, states that it represents some key factors which contribute to the analysis of the hazard potential for destruction, threat to life and economic loss from significant disaster agents (Wyoming Hazard Vulnerability 1977). It then goes on to declare that the ultimate outcome of the study is the development of a comprehensive disaster preparedness program for the State of Wyoming aimed at: (1) Reducing the incidence of and the vulnerability of the people to disaster events, (2) Establishing an effective disaster response capability and (3) Expediting the rapid recovery from disasters through prompt and efficient use of assistance programs. The document conveys that its immediate objectives are to identify the natural and man-made hazards to which the State is subject, prioritizing those hazards which have the potential of expanding beyond the capability of local effort and recommending measures which would both decrease the probability of a disaster occurrence and mitigate the effects, should a disaster strike.

The use of the term vulnerability in the title of this report seems to be very erroneous in light of the fact that a mere three-quarters of a page was devoted to the evaluation of the people who live in Wyoming. This document seems to focus more on the potential and actual impact of disaster events than it does vulnerability. A table on the final page of this document denotes this fact with its depiction of 'Disaster Effects by County', in which it rates each county as either high, moderate or low risk. This document neither shows us vulnerabilities, nor does it explain the processes involved with determining vulnerability. The time in which the document was completed might be one of the major reasons behind the lack of understanding in the vulnerability arena, but more recent studies have shown much the same approach to vulnerability analysis.

North Dakota's Hazard Vulnerability Analysis, completed in 1977, furthers the argument that vulnerability assessments have been dealt with on the same level as risk assessments. This document identifies the major hazard phenomena which pose a significant threat to life and property within North Dakota (Fuher 1977). It looks at what has happened in North Dakota and suggests that from studies of actual and probable occurrences we can develop plans for the most recurrent and probable kinds of hazard phenomena (Fuher 1977). This study shows another example of lack of knowledge about terms. It states, while discussing vulnerability to flood events, that the highest rate of vulnerability exists in areas which have continued to build in the identified flood plain areas (Fuher 1977). This report does not mention socioeconomic factors, age, sex, or education as factors that influence vulnerability, but focuses solely on the locational aspect of the people. This Vulnerability Analysis uses many of the same techniques as the other 'early' vulnerability studies, such as tables showing disaster effects in terms of severe to minimal damage and hazard potentials for all the counties in the state. It does not touch on the true vulnerability of the people, rather it discusses the issue on a macro-scale. Fuher (1977) concludes that the analysis took into consideration the past history of disasters in the state and the potential for a particular type of emergency situation. He goes on to state that until disaster prediction develops into a more exact science, conclusions from such analyses as these must be general rather than specific. Cover to cover, this report does not show us vulnerability, rather it represents an attempt to report on disaster probabilities with the acknowledgment that prediction has yet to become a precise science.

A more acceptable example of vulnerability assessment was undertaken in 1993 by Chang *et al.* (1993). This study stated that its focus was to obtain information and to assess seismic vulnerability of highly occupied or heavily used essential facilities, including schools, hospitals, fire stations, and bridges, in 20 counties in western Tennessee that may be strongly affected by earthquakes in New Madrid seismic zones. The study used a cost-effective preliminary seismic vulnerability evaluation system developed for Memphis and Shelby counties. The document depicted what criteria were to be used in the study, how the study was conducted, and included study results that will be important for future facility maintenance and improvement, earthquake loss estimates, seismic hazard/risk reduction, and earthquake preparedness/rescue plans in the region. This assessment appears at first glance to be along much the same lines as the other vulnerability studies reviewed, but upon further examination it is evident that this report has done what it set out to do. The main difference between this and the previous reports is that the human element was removed from the assessment rather than given the slight inclusion they were in the other studies. This document was not intended to identify human vulnerability, where the other studies attempt to give human vulnerability without taking all of the elements of vulnerability into account. This study provides a successful example of a screening procedure for prioritizing of essential facilities in an earthquake prone region in the central United States.

Petak, Atkisson and Gleys (1978) calculated the vulnerability of US populations to nine natural hazards: earthquakes, landslides, expansive soil, riverine flooding, storm surge, tsunami, tornado, hurricane, and severe wind. They derived expected annual losses by multiplying the probabilities of various intensities of hazards by the value of the physical structures, and adding results for all locals for which calculations were completed. They also computed estimated losses of life, housing units lost, residential dislocation, and unemployment resulting directly from natural hazards. The authors found that the vulnerability to natural hazards of the American population is seriously increasing. Indeed, vulnerability is increasing, but by what order of magnitude are people becoming more vulnerable. This book gives us the idea that Americans are more vulnerable now than ever, but it does not show us statistics that are relevant to individuals. These authors seem to have given us more of a risk analysis than a vulnerability assessment.

The State of Washington Hazard Vulnerability Analysis (1996) shows much of the same inequities as the above vulnerability analyses. Its purpose, as stated in the introduction, is to provide information on potential large-scale hazards which exist within or which could impact Washington State. The report is intended to serve as a basis for state-level emergency management programs and to assist local jurisdictions in the development of similar documents focused on local hazards. This document is to be the foundation of effective mitigation, preparedness, response, and recovery activities. Once again, the term risk potential becomes a synonym for vulnerability when in fact it refers to quite different aspect of the disaster realm. This analysis is typical of most that have been researched in that it focuses on the physical hazard rather than on the actual vulnerability of persons within Washington State.

The more recent *Kitsap County Hazard Vulnerability Study* (1998) states that it is an element of hazard mitigation allowing emergency managers to set goals according to the public need for protection. It suggests that it enhances public and private agency understanding and awareness, influencing the adoption of hazard mitigation programs. Finally, this analysis supposedly reveals findings that serve as a basis for preparedness as well as influencing effective response and recovery programs. The above statements convey the message that this analysis of the vulnerability of Kitsap County is thorough and all encompassing, yet the opposite is actually true. This document is yet another attempt that falls into the realm of risk identification rather than vulnerability analysis. It points out the obvious elements of risk that are encountered within the county, but does not touch on the elements of vulnerability as discussed earlier.

Two studies, one published very recently and the other dating back to 1973 seem the most relevant when dealing with social vulnerability. These studies, *A GIS-Based Hazards Assessment for Georgetown County, South Carolina* by Susan Cutter (1997) and Social Vulnerability in Indianapolis by John Maloney (1973) use a definition of vulnerability assessment that includes statistical analysis of demographic characteristics to determine the areas that contain the most vulnerable populations. Maloney appears to be a pioneer in the area of vulnerability as his research took place nearly thirty years ago. Although Maloney does not include vulnerability to specific hazards, he does include valuable insight into the characteristics that make persons more or less vulnerable on a social level. Cutter's (1997) study does not specifically reference Maloney's earlier attempt to quantify vulnerability, yet this study appears to be rooted in the same theoretical framework as it's earlier counterpart. Both of these studies provide invaluable information on the areas of a community or society that currently contribute the most to a proper definition of vulnerability.

Conclusion

In summary the literature was searched to determine first, the most effective meanings of the words "risk" and "vulnerability". Once proper and all encompassing definitions of these terms are put into academic, research and government circles, the groundwork for good hazards research has begun. The literature was also searched for the current level of research pertaining to the methodology of risk assessment methods. The equations of social vulnerability to hazards put forth by the above authors provides a much needed platform on which to advance in the field of hazard risk assessment. Finally, the literature review attempted to determine the theory behind a sound methodology of vulnerability assessment. Equations and theories on this topic assist research in the area of vulnerability assessment by suggesting key elements involved in determining overall community vulnerability to natural hazards.

Research has shown that a large gap in the literature exists in the areas of multiple hazard risk and assessment definitions, methods and theoretical frameworks. Moreover, the terms risk and vulnerability have often been viewed as two sides of the same coin. Attempts at risk and vulnerability assessments have proven that research into these fields is merely in the beginning stages. What is needed is a level of communication among researchers that strives to gain an understanding of key terms in the field of natural hazards assessment. With an easily followed natural hazards terminology there would most likely be a better flow of ideas and concepts that could lead to a more entire understanding of risk and vulnerability. It is important then, that greater consideration be given to the advancement of ideas along the lines of vulnerability assessment methodology to ensure a sound base for future research in this area.

Chapter Three

Methodology: Design and Procedures

Introduction

The above literature review suggests that one of the existing problems in the field of natural hazards research is that no attempt has been made to quantify vulnerability to multiple hazards. Planning and regulation, along with countless number of people have suffered because of this gap in hazards research. There is no successful way to deal with this problem without a true scale of vulnerability.

This thesis proposes that by quantifying the qualitative research that has been accomplished in the field of vulnerability it is possible to advance a theoretical framework on this subject. Theoretically one could assign values to the elements of vulnerability, manipulate those figures and establish a quantitative scale of vulnerability. Such a scale would have an enormous impact in the planning and regulatory fields, as well as on personal levels. The implications of a true vulnerability scale are so far reaching that it seems impossible to believe that the research has grown scarce in this field. People, towns, cities and nations would turn the corner of progress if they were aware of the slight changes that could be made in lifestyle or current economic condition that would change their vulnerability to natural hazards. Resilience to hazards would improve, and the often "long road to recovery" to the status quo could be avoided. Communities would be able to cope better with natural hazards before during and after the actual disaster event.

Using the criteria discussed above it is hypothesized that:

1) Socioeconomic factors are the most important in determining vulnerability. As wealth increases, the ability to cope with disaster also increases. Poorer people are often at a disadvantage during disasters and in the post disaster phase because lack of resources often leads to inability to return to "normal".

2) Age and gender are both major contributors to the process of vulnerability. As stated above older people are often less mobile and less healthy than younger people leading to an inability to escape hazards and often a decreased ability to regain their pre-event health and economic status. Gender has also been seen as an indicator of vulnerability. Because females are usually seen as family caregivers and at times have smaller social support structures than males, they are often perceived as more vulnerable to hazards. Women will normally decide to stay with home and family in disaster times, while men, because of their cultural roles, have been shown to have a greater ability to escape the confines of the home during disaster events and in the post disaster process.

3) Housing type and status (renting or owning) are both included in a proper determination of vulnerability. Mobile homes and lower quality housing types have been shown to lead to greater vulnerability during hazard events. These types of structures are less able to withstand the immense stress brought forth by natural disasters. This lack of housing quality puts the persons residing in them at greater vulnerability pre and post disaster. The fact that persons live in lower quality housing points back to economic

status. Normally, if more assets were available, the quality of housing would be better, effectively lowering vulnerability. During a hazard event this lack of protection leads to a much greater loss of property and assets, thus less ability to rebound from a disaster. In addition, persons who rent houses, apartments, and condominiums have been shown to be more vulnerable during hazard events. Lack of renter's insurance, often because of affordability, leads to a downward spiral during and after a disaster event. Renters are often unable to cope economically with disasters due to the fact that they have no coverage on their possessions, thus little or no ability to rebound and return to normal in post disaster times.

4) Population density and housing density both help to identify the level of vulnerability. Simply stated, the more people that occupy any single area and the more development in an area, the less able that area is to cope with natural hazards. Increased population puts a strain on goods and services available for consumption coupled with over development effectively declining the ability of the environment to naturally cope with disaster events.

Research Questions

The research questions to be investigated in this study (see details on page 2) are; first, how census blocks in Hillsborough County have been classified at risk to individual natural hazards, multiple natural hazards and whether or not the census blocks have been assessed for characteristics of vulnerability to the effects of natural hazards? Literature was reviewed to determine if the county has been analyzed for risk to hazard events and to determine the extent to which research in this area has been taken. In addition, literature was reviewed to determine what measures have been taken in the area of individual and multiple hazard risk classification in Hillsborough County and to ascertain if any previous research has delved into the area of social characteristics that might lead to increased vulnerability during and post disaster events.

The second and third research questions were aimed at determining the current risk of census blocks in Hillsborough County to individual and multiple natural hazards. The process involved in answering these questions included manipulating and querying data in Arc View to produce shape files and data tables showing the areas impacted by individual and multiple hazards.

The final research questions were designed to discover the most important characteristics that influence vulnerability to individual and multiple natural hazards. Attempting to answer these questions involved analysis of Hillsborough County census data at the block level.

Individual Hazard Risk Assessment

The purpose of this portion of the research is to gain an awareness and understanding of the most risky locations within Hillsborough County, Florida. GIS risk coverages were produced using Hazmit (Hillsborough County Hazard Mitigation Team) data, specifically TAOS (The Arbitrator of Storms) data. This information was useful in deciding which census blocks are most at risk to physical hazards. Also, facts gained here should benefit policy makers and homeowners as a new source of information on possible threats to livelihoods and lives.

Individual risk assessments were investigated through the use of GIS coverages of Hillsborough County in 1990, together with TAOS (The Arbitrator of Storms) coverages of the region. The TAOS coverages include data on wind speeds, standing water depth and storm surge for category tropical storm through category V hurricane. These data, unioned with Hillsborough County census block data, enabled the determination of which areas are affected the most by a host of natural hazards. The following shape files are included in the TAOS coverages:

> Wind speed in MPH, Water Depth in Feet Above Elevation, Wave Height alone in Feet, Debris quantity in Cubic Yards per Acre, Single Story Flooding Due to Surge Damage Multiplier for Structure, in percent of structures value destroyed, Single Story Flooding Due to Surge Damage Multiplier for structure, in percent of content destroyed of a structure, Multiple Story Flooding Due to Surge Damage Multiplier for structure, in percent of structures value destroyed, Multiple Story Flooding due to Surge Damage Multiplier for contents of structure, in percent of contents value destroyed; Mobile Home Flooding Due to Surge Damage Multiplier for structure, in percent of structures value destroyed, Mobile Home Flooding Due to Surge Damage Multiplier contents for structure, in percent of contents value destroyed of a structure; Wood Frame composite Damage Multiplier, in percent of structures value destroyed; Wood Frame Composite Contents Damage Multiplier, in percent of contents value destroyed; Wood Frame Wave Damage Multiplier, in percent of structures value destroyed; Wood Frame Wind Damage Multiplier, in percent of structures value destroyed; Wood Frame Contents Damage Multiplier, in percent of contents value destroyed of a structure.

Also, the above five fields continue repeating for the following construction types: Concrete Block, Mobile Home, and Commercial. Included in these data are parcel information from the county specifying:

Tax identification number; township, range, and section; property type; land use code; Construction classification; Property type classification; Assessed value of the structure and land; Purchase price of the land; Improvements made to the land and structures; Value of the contents of the structure; Flood due to surge level; Number of buildings on the parcel; Wave damage multiplier in percent of structure destroyed; Wave damage multiplier in dollar value; Wind damage multiplier in percent of structure destroyed; Wind damage multiplier in dollar value; flooding due to surge damage multiplier in percent of structures value destroyed; flooding due to surge damage in dollars; All damage multiplier- wave, wind , and flooding due to surge combined in percent of structures value destroyed; All Damage- wave, wind, and flooding due to surge combined in dollar value; Wind Damage Multiplier for contents of structure in percent of contents destroyed; Wind damage for contents of structure, in dollars; Flooding due to Surge Damage Multiplier of contents of structure in percent of contents value of structure destroyed; Flooding due to Surge Damage for contents of structure in dollars.

These data were useful in locating the most risky places within Hillsborough County. Other data that were used to determine risk are a GIS coverage of the 100 year, 500 year and 600 year flood plains, and a sinkhole coverage of Hillsborough county and supporting literature on sinkhole frequencies and distributions throughout Hillsborough County in the form of the geological report, Sinkhole Development in Hillsborough County, Florida.

The delineation of which individual hazards have the potential to impact Hillsborough County was undertaken through the following steps:

Hurricane Hazard data was used in the identification of hazard areas based on wind speeds, water depth and storm surge. The potential impact and effects of hurricane hazards were found in six different shape files within the TAOS data. These shape files were analyzed separately as they contain information specific to each category storm. Also, the shape files for each storm were examined for the effects of storm surge, water depth and wind speed. The procedure to identify the impact of each of these hazards is as follows. Initially, a selection query was made in order to narrow the data fields to only the desired information. In the case of water depth greater than one foot deep, the shape file was queried on the field "water depth" and data were extracted only for those areas that would potentially experience a standing depth of water greater than one foot. This one foot designation was chosen as an arbitrary mark of the loss of functional electricity due to the inundation of electrical circuitry inside a household. This selection query successfully delineated those areas of Hillsborough County that would be impacted by standing water depth greater than one foot deep. These selected data sets were then converted into shape files in order to preserve the data for future examination. The same "water depth" query and shape file conversions were initiated on each of the other five data sets, covering all of the categories of tropical cyclone that have the potential to impact Hillsborough County.

Next, storm surge was delineated using only the TAOS hurricane category V shape file because the category V shape file was the only shape file that contained data for all of the other category storms. Data for this aspect of the identification process was found to be incomplete, or assigned improperly in the attribute table. The field labeled "Category" did not, in all instances, correspond properly to the actual category storm. Table editing was able to correct these errors, allowing the delineation process to continue. This shape file was queried by category in order to initiate the process of identifying the impact of each individual storm surge. Once this query was accomplished for each category, the selected data sets were converted into shape files so that future analysis of the data could be accomplished.

Finally, winds speeds for each of the six categories of tropical cyclone that have the potential to impact Hillsborough County were delineated. This was accomplished by querying the data field wind speed for each category storm. This selection query was based on the data field "wind speed" in each shape file and selected only those areas that experienced winds greater than the lower limit for each category storm (i.e. A category III hurricane was only appraised for those areas that had wind speeds of at least 111 miles per hour). This process was concluded by converting each of the selections into shape files for future analysis.

Tornado Hazard occurrence data for Hillsborough County was found at the NOAA (National Oceanic and Atmospheric Administration) web site. This web site provided a Tornado History Data, 1998, which included hail and wind data files in an archaic coded format originally used in an old Data General mainframe computer database. This file provided all of the tornado, hail and wind data from the time frame 1950-1995, including starting points of the events. This table was saved as a database file (DBF) and imported into Microsoft Excel. These data were then decoded using a decode file provided by NOAA and delineated based on type of event. The locations of the tornado events were established after the table was culled of unnecessary information. These latitude and longitude locations were then converted into decimal degree locations and saved as a DBF file. This file was imported into Arc View and projected as a point theme based on the decimal degrees of each point. A selection query was then performed on this point theme in order to delineate only the tornadoes that have impacted

Hillsborough County. This selection was then converted into a shape file and saved for future investigation. The attribute table for this theme was edited to include, where available, information pertaining to F-scale, tornado width and length. However, because Hillsborough County does not normally experience tornadoes high on the F-scale, information of this matter was not necessary to complete this portion of the analysis.

Sinkhole Hazard occurrence data for Hillsborough County was found in the Florida Sinkhole Index, 1995. These data were separated by county and arranged by latitude and longitude position. These data were scanned into a Microsoft Excel spreadsheet format. Once in a workable format, all of the positions were converted into decimal degrees and imported into Arc View as a DBF. This DBF was then projected as a point coverage and converted into a shape file and saved for future investigation.

Flood Hazard data for Hillsborough County were found on one shape file. This shape file consisted of data on the 100 year, 500 year, and 600 year flood events. This shape file was queried in order to delineate between the different flood events. Each selection was then converted into individual shape files for future examination. However, the 600 year flood data were found to be corrupted and thus discarded from data analysis. These data, upon delineation and review showed that their impact areas were the same as a portion of the 100 year flood.

Multiple Hazard Risk Assessment

After maps and statistics of single hazard events were compiled and evaluated to consider the areas in Hillsborough County most at risk to individual hazard events, it was then the object of this research to outline the most risky locations to multiple hazards.

The process involved in the preparation and data manipulation for this portion of the research is as follows:

Multiple hazard risk assessments were investigated through the use of GIS coverages of census block data for Hillsborough County in 1990, together with the single hazard risk coverages from the previous section. An initial examination of simple overlays showed the areas that are affected by all of the above stated hazards, although it is thought that almost all of Hillsborough County is included in such a coverage. An analysis of Hillsborough County's risk potential was completed based upon risk analyses put forward by authors Montz (1994) and Petak and Atkisson (1982). Caution was used in this area of research as Montz (1994) suggested that a difficulty may arise in the analysis of these results because of the fact that different geophysical events affect smaller or larger areas and because of the different levels of development that may exist within the communities. The process of identifying multiple hazard risk was undertaken as follows:

The shape files produced in the individual hazard risk assessment portion of the research were analyzed in conjunction with census block data to determine exactly which census blocks would be impacted by which events. This was accomplished by selecting from the census data those blocks which intersected the impact areas of the individual hazards. These census blocks were then converted into individual shape files based on each hazard. For example, the data included in a category I hurricane resulted in the production of three separate shape files delineating the areas impacted by category I wind speeds, water depth greater than one foot, and storm surge. Similar shape files were produced for each of the hazards being evaluated. A total of twenty-two shape files showing the exact census blocks impacted by each hazard were produced, including three each for category tropical storm through category V, one delineating census blocks impacted by tornadoes, one showing census blocks affected by sinkholes, and two displaying census blocks impacted by the 100 year and 500 year floods respectively.

These shape files were then overlaid and analyzed in order to define the census blocks that have the potential to be affected by multiple hazards. This overlay was then queried by the "hazard" field in order to establish a worst case scenario which included only those areas impacted by hurricane category V wind speeds, water depth, storm surge, sinkholes, tornadoes and the 100 and 500 year flood events. This selection was then converted into a shape file and saved for future examination.

Vulnerability Assessment

The object of this portion of research was to delineate the most important characteristics to vulnerability and compose a theoretical framework that when used would accurately depict vulnerability on the individual or community level.

The census blocks of Hillsborough County were appraised for the following characteristics: Socioeconomics, gender, age, race, total population, total housing units, number of mobile homes, and housing status. A framework for establishing a vulnerability scale was the end result once these characteristics have been identified and statistically analyzed. This research was testing this theory through the use of a summation model in order to derived a more clear understanding of vulnerability. With the use of this framework, determining the vulnerability of a community was accomplished by plugging the necessary information into the equation.

This model was tested through the use of Arc View. Shape files defining communities in Hillsborough, more accurately, census blocks within these communities, were analyzed in order to define values for the proposed scale based upon individual characteristics on the block level. This application concluded with a visual depiction of the differences in vulnerability within each community, as well as demographic data to support these differences. This projection is more specific than past vulnerability projections in that it spans a range from 0 vulnerability to a rating of 8. Information of this nature was key in identifying the most vulnerable area, as well as areas that could have a change in vulnerability with the adjustment of a few of the key elements.

The above research suggested that a methodology for the assessment of vulnerability to natural hazards was necessary in order to advance in this ever changing field. By use of a definition of vulnerability that hinges on socioeconomic level, gender, age, population, housing density, number of mobile homes and housing status, such a theoretical framework is thus proposed. Through assigned values in each of these elements of vulnerability, a scale was designed to forecast actual vulnerability. The values of the vulnerability ratings were assigned based on a methodology by Susan Cutter in *Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina* (1999) as follows:

Each social variable was standardized by determining the ratio of that variable in each census block to the total number of that variable in the county (Cutter 1997, 20). For instance, in Table 1, the number of housing units in each census block was tabulated (column 2) as were the number of total housing units in the county (column 3). The ratio of the number of homes to the total number of homes for the county was derived (column 4). This value (X) was then divided by the maximum (X) value to create an index that ranges from 0 to 1.00. Higher final vulnerability scores suggest greater vulnerability due to this characteristic. Conversely, lower final scores suggest that this characteristic does not affect overall vulnerability to a great extent. This method of standardization was used on all of the social variables, with the exception of mean house value.

Table 2 visualizes the steps taken to develop mean house value scores. First, in order to eliminate the possibility of negative scores, the absolute value of the difference between block and county values was added. The difference between county and block housing was computed by taking the average of mean house value and subtracting the mean house value for each census block. The absolute value of the maximum X (column 4) was added to create Y (column 5) in order to remove possible negative numbers. Finally, the ratio of the new value Z to the maximum Y produced the mean house value score (column 6). With the use of the above equations, the determination of the vulnerability of specific census blocks was completed by adding all applicable criteria (i.e. if the average house value vulnerability score was 0.76, the dependent age score was 0.35, the female score was 0.58, the population score was 0.28, the housing score was 0.79, the mobile home score was 0.47 and the housing status score was 0.28, the block would have a total vulnerability score of 3.51, or a medium vulnerability). This overall vulnerability rating theme was converted to a shape file and saved for further analysis.

Table 1: Vulnerability characteristic scoring procedure

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)
Block 1	25,000	55,615	30,615	95,523	0.89
Block 2	13,500	55,615	42,115	107,023	1.00
Block 3	120,523	55,615	-64,908	0	0.00
Block 4	27,865	55,615	27,750	92,658	0.87
Block 5	68,721	55,615	-13,106	51,802	0.48
Block 6	98,123	55,615	-42,508	22,400	0.21
Block 7	33,333	55,615	22,282	87,190	0.81
Block 8	42,856	55,615	12,759	77,667	0.73
Block 9	74,985	55,615	-19,370	45,538	0.43
Block 10	51,249	55,615	4,366	69,274	0.65

(Source: Revised from Cutter, 1997)

Table 2: Mean house value vulnerability scoring procedure

Census Block	# of Homes in Block	Number of Homes in County	Ratio of Block to County (X)	Housing Vulnerability Score (X/maximumX)
Block 1	200	2,524	0.079	0.26
Block 2	105	2,524	0.042	0.14
Block 3	73	2,524	0.029	0.09
Block 4	94	2,524	0.037	0.12
Block 5	365	2,524	0.145	0.47
Block 6	781	2,524	0.309	1.00
Block 7	15	2,524	0.006	0.02
Block 8	23	2,524	0.009	0.02
Block 9	548	2,524	0.217	0.70
Block 10	321	2,524	0.127	0.41

(Source: Edited from Cutter, 1997)

The above steps used to identify the vulnerability of census blocks in Hillsborough County includes different vulnerability characteristics than the original model put forth by Cutter (1999). Cutter's social vulnerability equation included non-white persons in its attempt to define overall vulnerability, where this research theorized that renter populations constituted a greater vulnerability. Along these lines, Cutter's vulnerability equation was also applied to the census blocks of Hillsborough County. This equation produced similar, yet slightly divergent vulnerability scores than the researcher's. These differences were analyzed to determine the extent of deviation between the two equations.

When Community Risk Meets Community Vulnerability

This portion of research is aimed at identifying which areas of Hillsborough County, more accurately, which census blocks, are the most at risk and the most vulnerable to multiple natural hazards. Census block groups were used in this research because they are the smallest unit of social characteristics available from the government. Because of privacy acts, household census information is not available for public use, thus the use of census block groups, the next smallest available data base. In order to determine which areas fit into this category, the most vulnerable census blocks, or those blocks that had a vulnerability of 3.5 or greater on a scale of 1-8 were selected. These selected blocks were then converted into a shape file for further analysis. In addition, census blocks that had the potential to be impacted seven natural hazards were selected from the multiple hazard shape file produced earlier. This selection of census blocks was also converted into a shape file to be used for further investigation. These two shape files, the most risky locations and the most vulnerable locations, were then intersected to determine which census blocks, if any, were both the most risky and most vulnerable. The result of this intersection was converted into a shape file and saved for later examination of the characteristics of the areas and the demographics of the people residing in those areas.

Chapter Four

Data Results and Analysis

Introduction

This chapter is divided into six sections. The first section, *Individual Hazard Risk Assessment*, includes a report on the data pertaining to natural hazard risk in Hillsborough County. These data were derived from Hillsborough County census block shapefiles, TAOS shapefiles, and shapefiles created from historical sinkhole and tornado data. The second section of this chapter, *Locational Risk Assessment*, reports on the data pertaining to the most risky locations in Hillsborough County. The third part of this chapter, *Multiple Hazard Risk Assessment*, describes the data pertaining to community vulnerability in Hillsborough County. These data were formulated through the statistical manipulation of information from Hillsborough County census block shapefiles. The fourth section of this chapter, *Community Vulnerability Factors*, addresses the social factors found in Hillsborough County that could serve to increase or decrease vulnerability. These characteristics were analyzed for each block group in relation to the characteristics of entire county. The fifth part of this chapter, *Overall Community Vulnerability*, focuses on the analysis of the most vulnerable communities in Hillsborough County and on the census blocks that were found to have very disparate scores in comparison to vulnerability equations put forth in Cutter's (1997) study of social vulnerability. The sixth section of this chapter, *When Community Risk Meets Community Vulnerability*, presents an analysis of the census blocks of Hillsborough County that are both the most risky and the most vulnerable.

Individual Hazard Risk Assessment

The population of Hillsborough County is increasing. This seemingly never ending influx of people somehow find space in a city that is quickly developing all available land. This population increase brings with it new challenges for city planners and local officials. Unfortunately, the safety of these newcomers is often compromised by the need for housing. Research was undertaken along these lines to determine which natural hazards have the potential to affect Hillsborough County the greatest. Hazards affecting these areas are hurricane storm surge, winds and water depth and riverine flooding.

The hurricane hazard that threatens Hillsborough County is perhaps the single most destructive event that could impact the county. The following figures serve as an introductory look at the areas that would be impacted by tropical storm hazards through category V hurricane hazards. These figures include impact by hurricane storm surge, wind speeds and standing water depth greater than one foot.

- Figure 13 portrays the extent of storm surge that would occur in Hillsborough County for each category of tropical cyclone.
- Figure 14 and Figure 15 show the extent of water intrusion and wind speeds that would occur during a tropical storm event in Hillsborough County.

- Figure 16 and Figure 17 show the extent of water intrusion and wind speeds that would occur during a category I hurricane event in Hillsborough County.
- Figure 18 and Figure 19 portray the extent of water intrusion and wind speeds that would occur during a category II hurricane event in Hillsborough County.
- Figure 20 and Figure 21 show the extent of water intrusion and wind speeds that would occur during a category III hurricane event in Hillsborough County.
- Figure 22 and Figure 23 display the extent of water intrusion and wind speeds that would occur during a category IV hurricane event in Hillsborough County.
- Figure 24 and Figure 25 visually represent the extent of water intrusion and wind speeds that would occur during a category V hurricane in Hillsborough County.

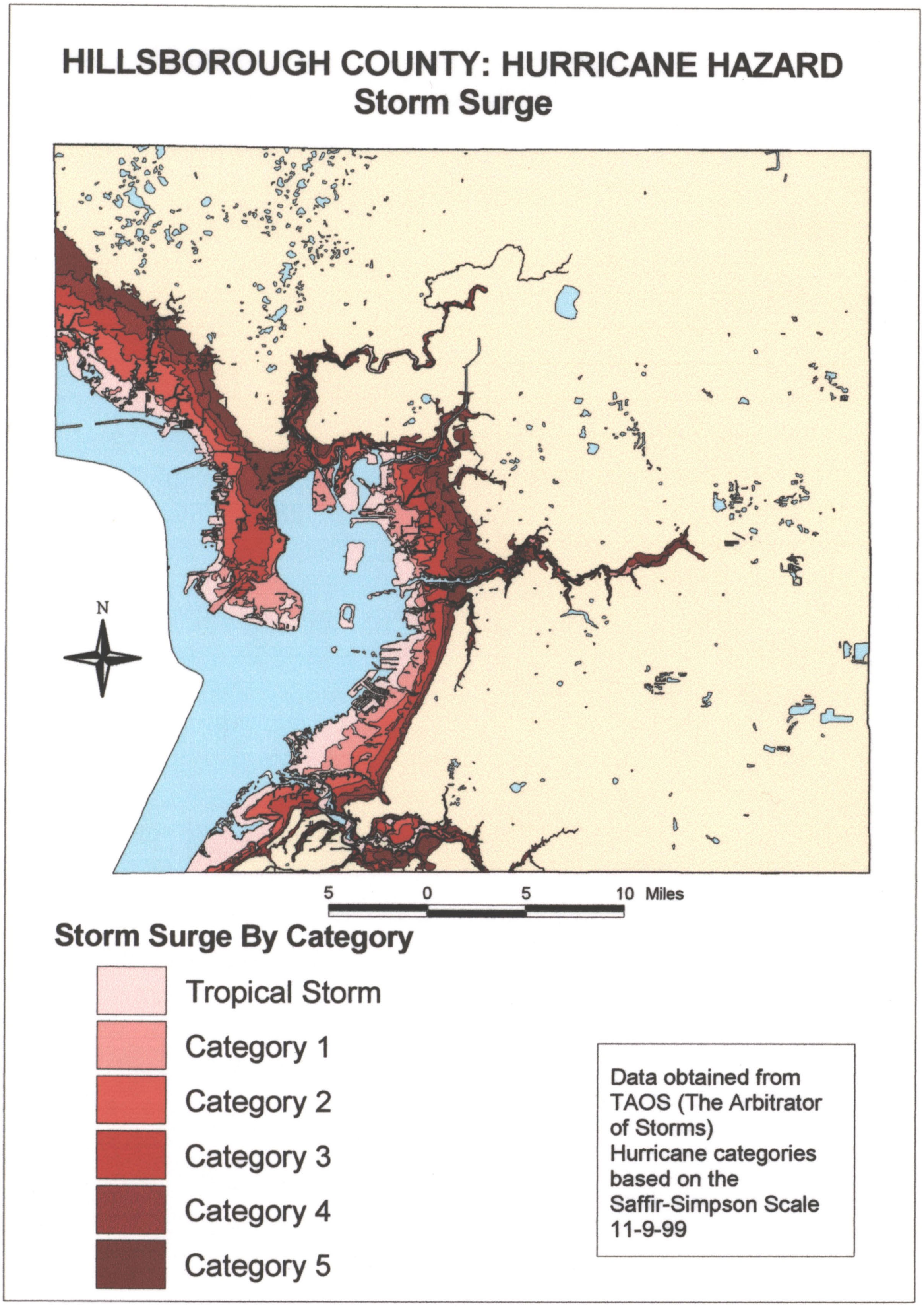

Fig. 13: Hillsborough County - Areas impacted by tropical storm through category V storm surge.

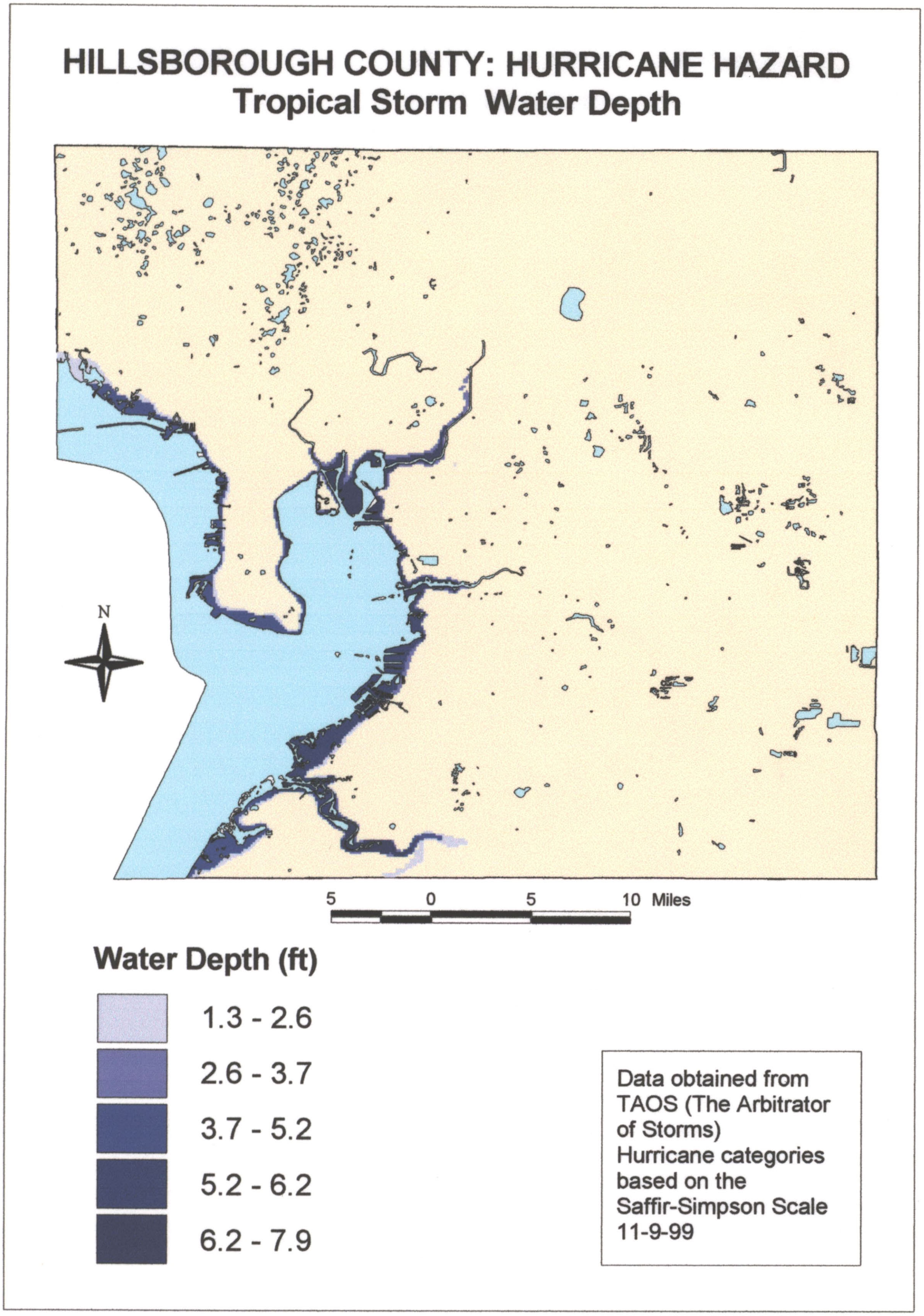

Fig. 14: Hillsborough County - Areas impacted by tropical storm water depth greater than one foot.

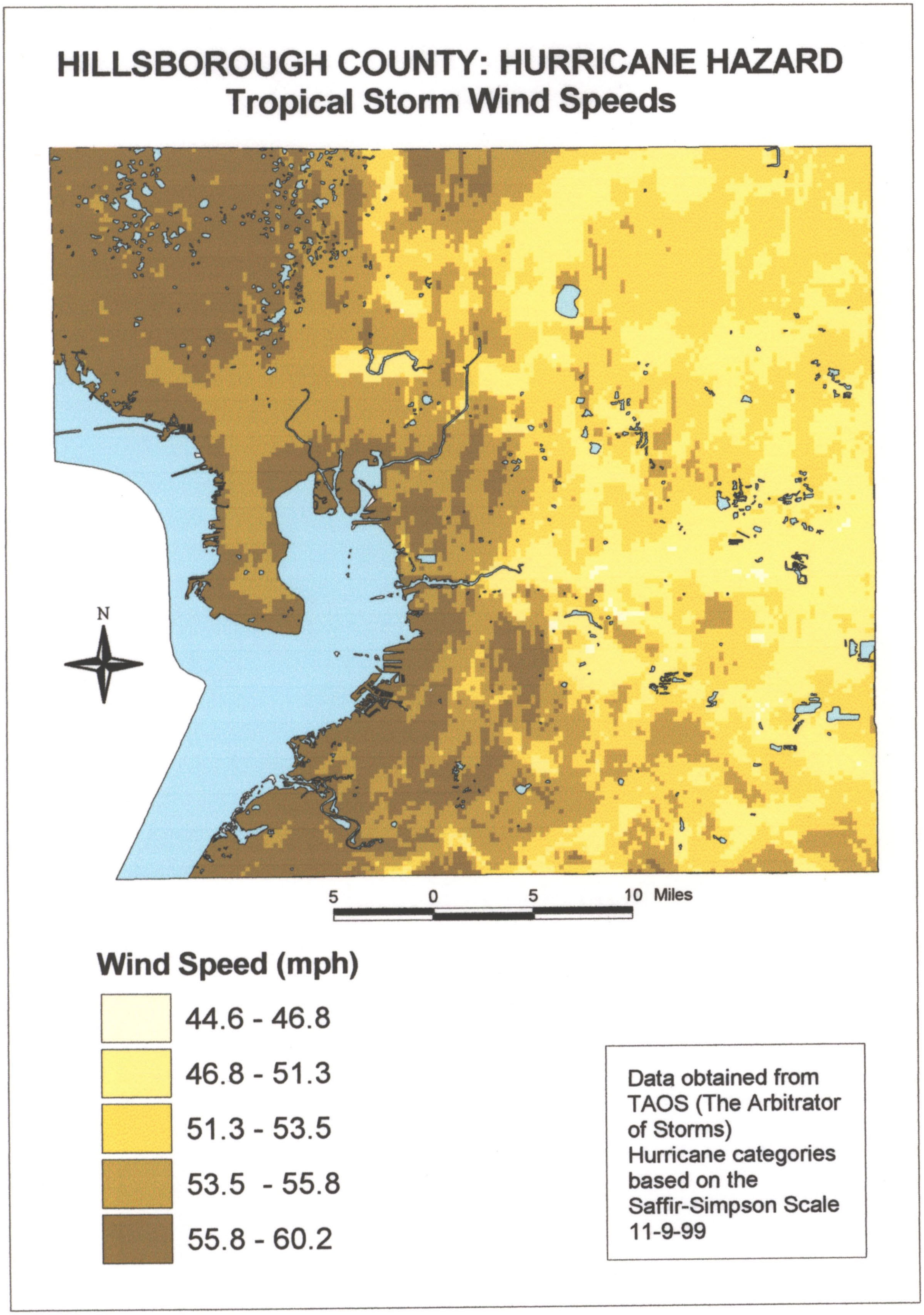

Fig. 15: Hillsborough County - Areas impacted by tropical storm wind speeds

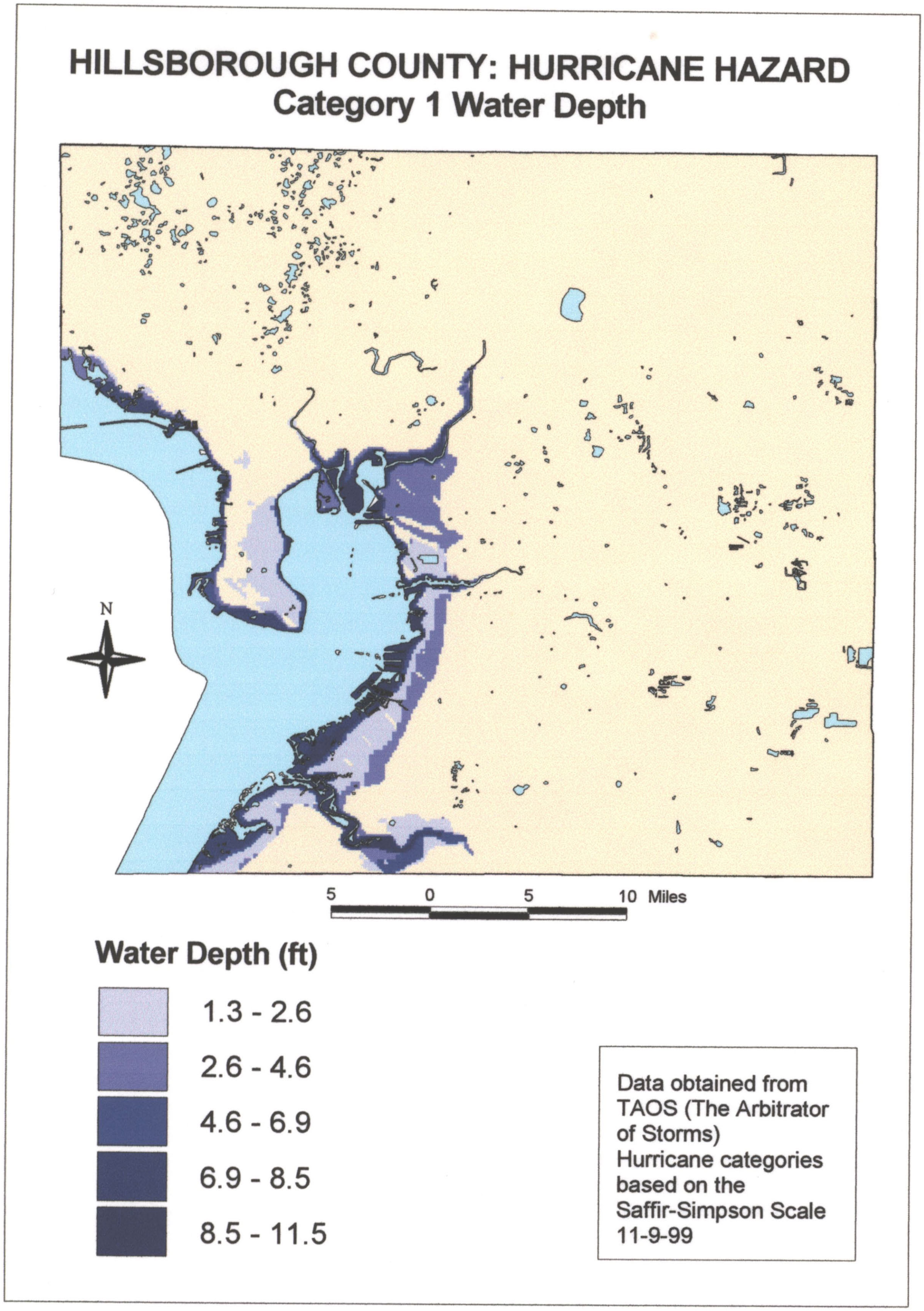

Fig. 16: Hillsborough County - Areas impacted by hurricane category I water depth greater than one foot.

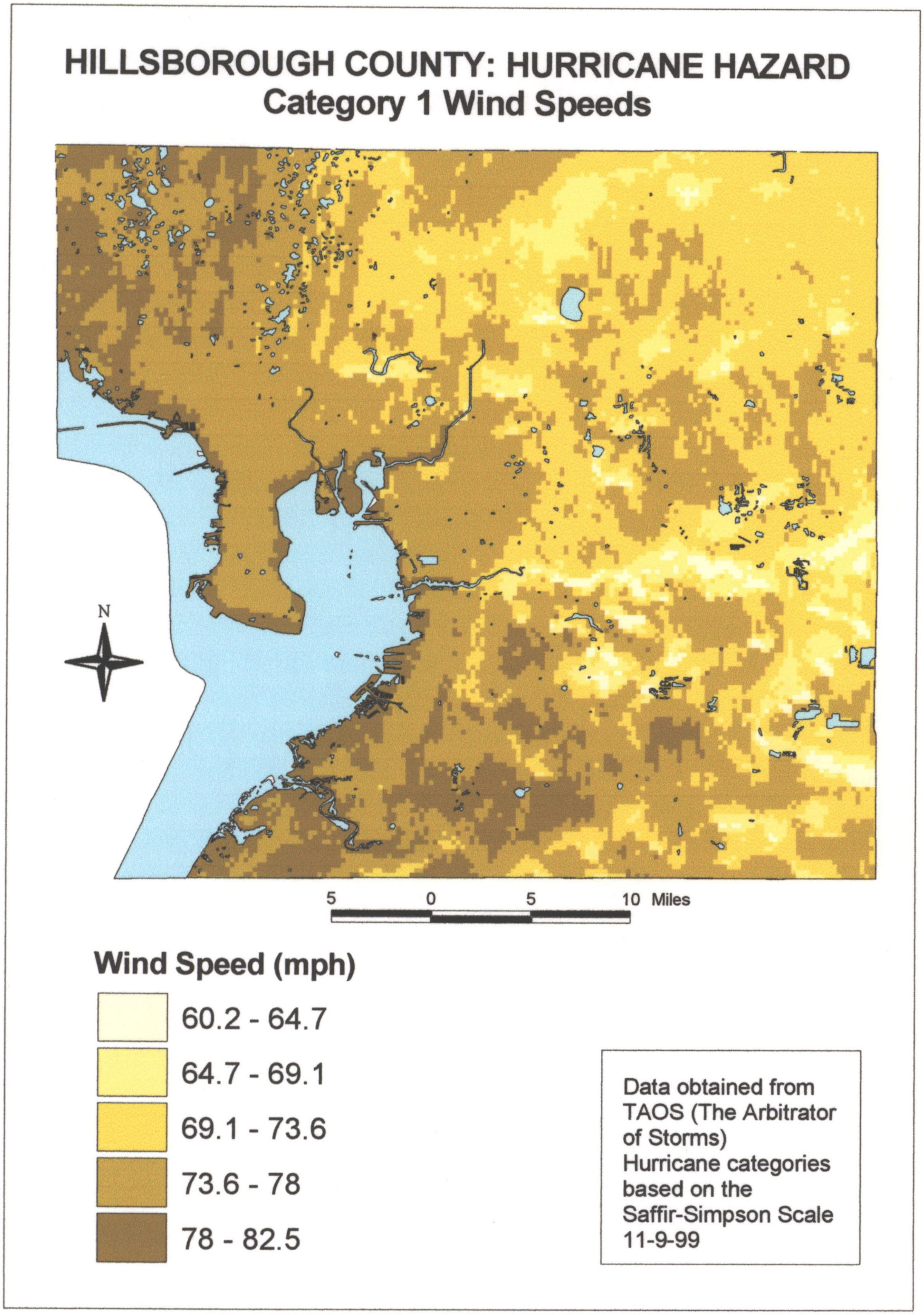

Fig. 17: Hillsborough County - Areas impacted by hurricane category I wind speeds.

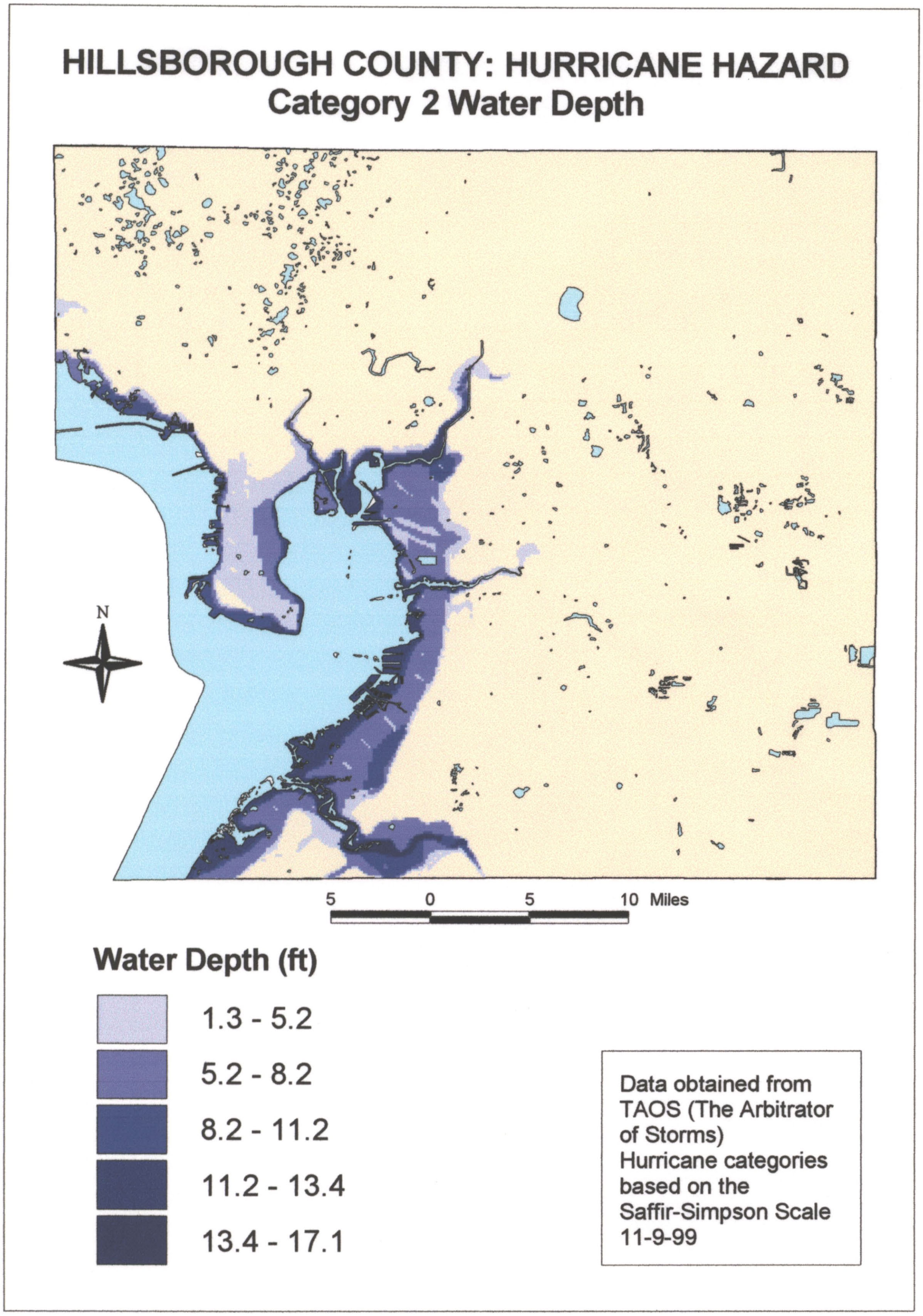

Fig. 18: Hillsborough County - Areas impacted by hurricane category II water depth greater than one foot.

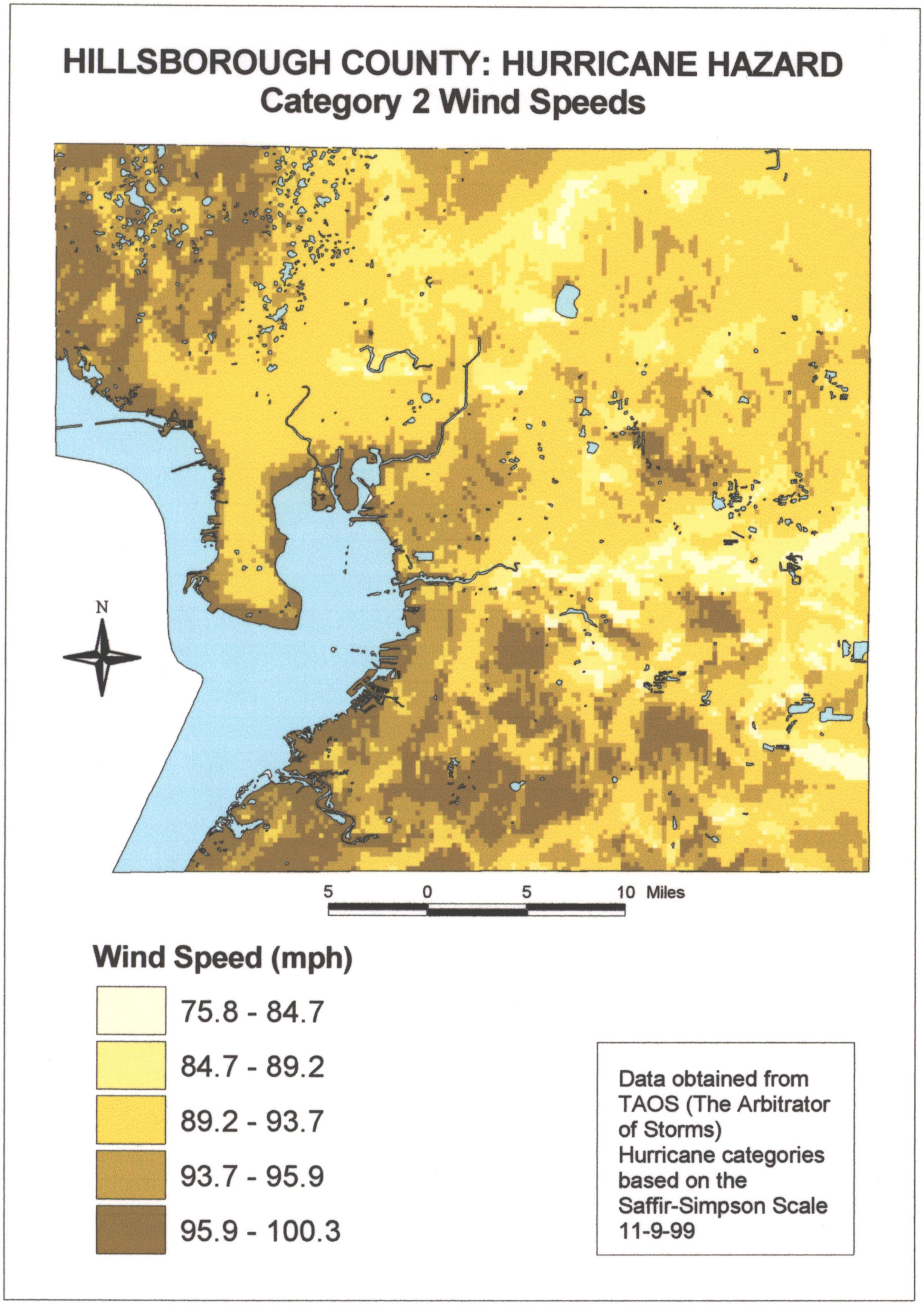

Fig. 19: Hillsborough County - Areas impacted by hurricane category II wind speeds.

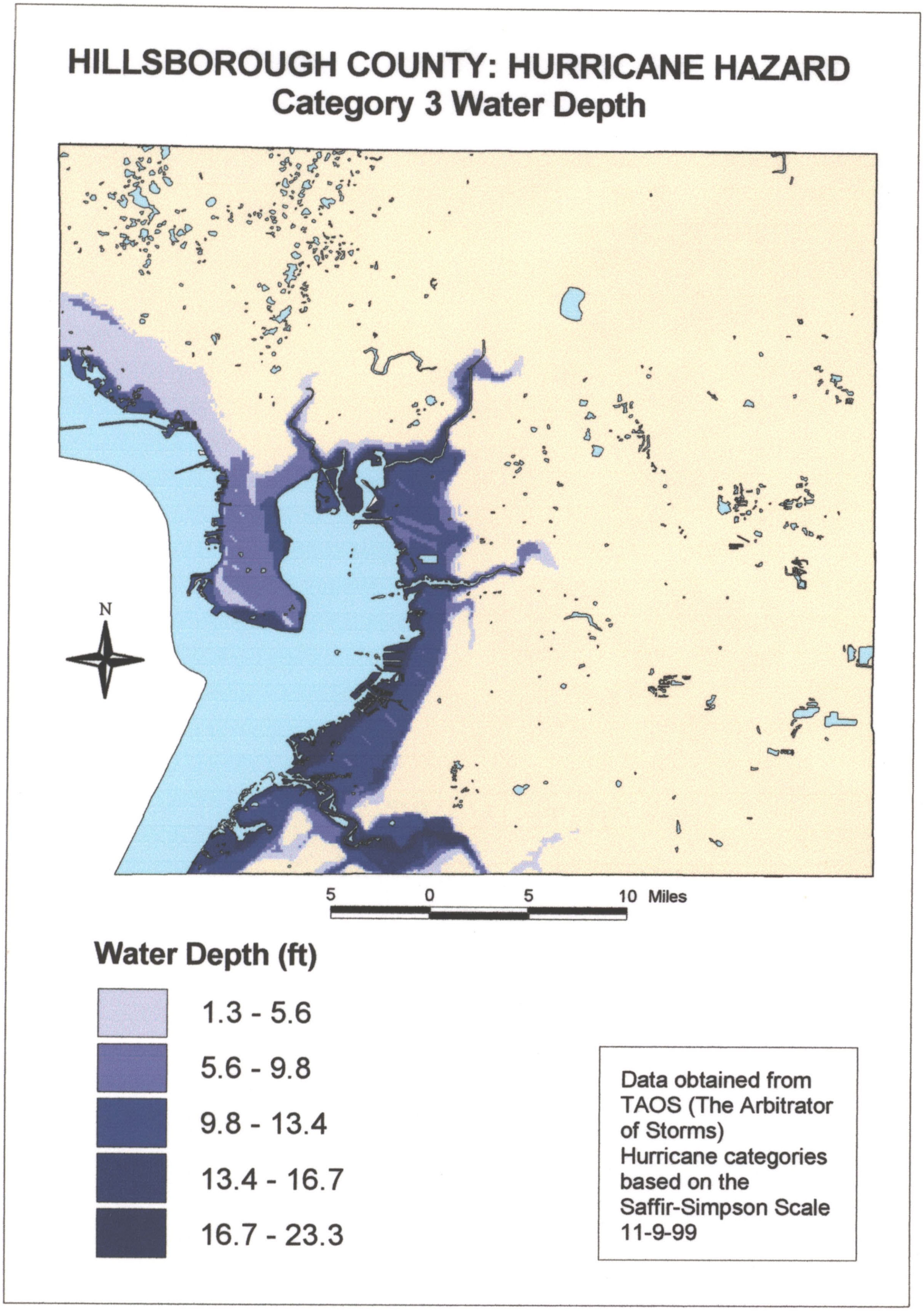

Fig. 20: Hillsborough County - Areas impacted by hurricane category III water depth greater than one foot.

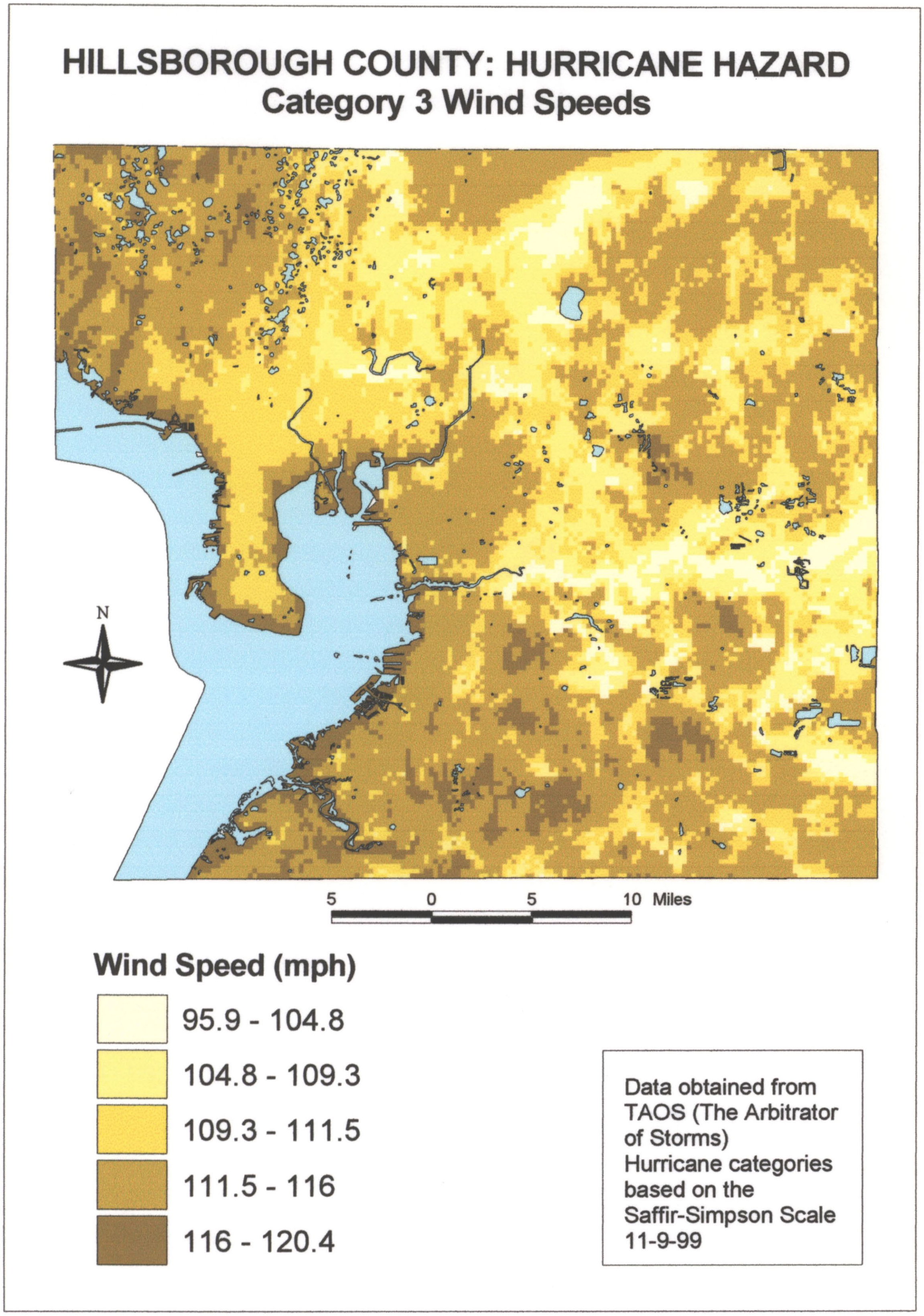

Fig. 21: Hillsborough County - Areas impacted by hurricane category III winds speeds.

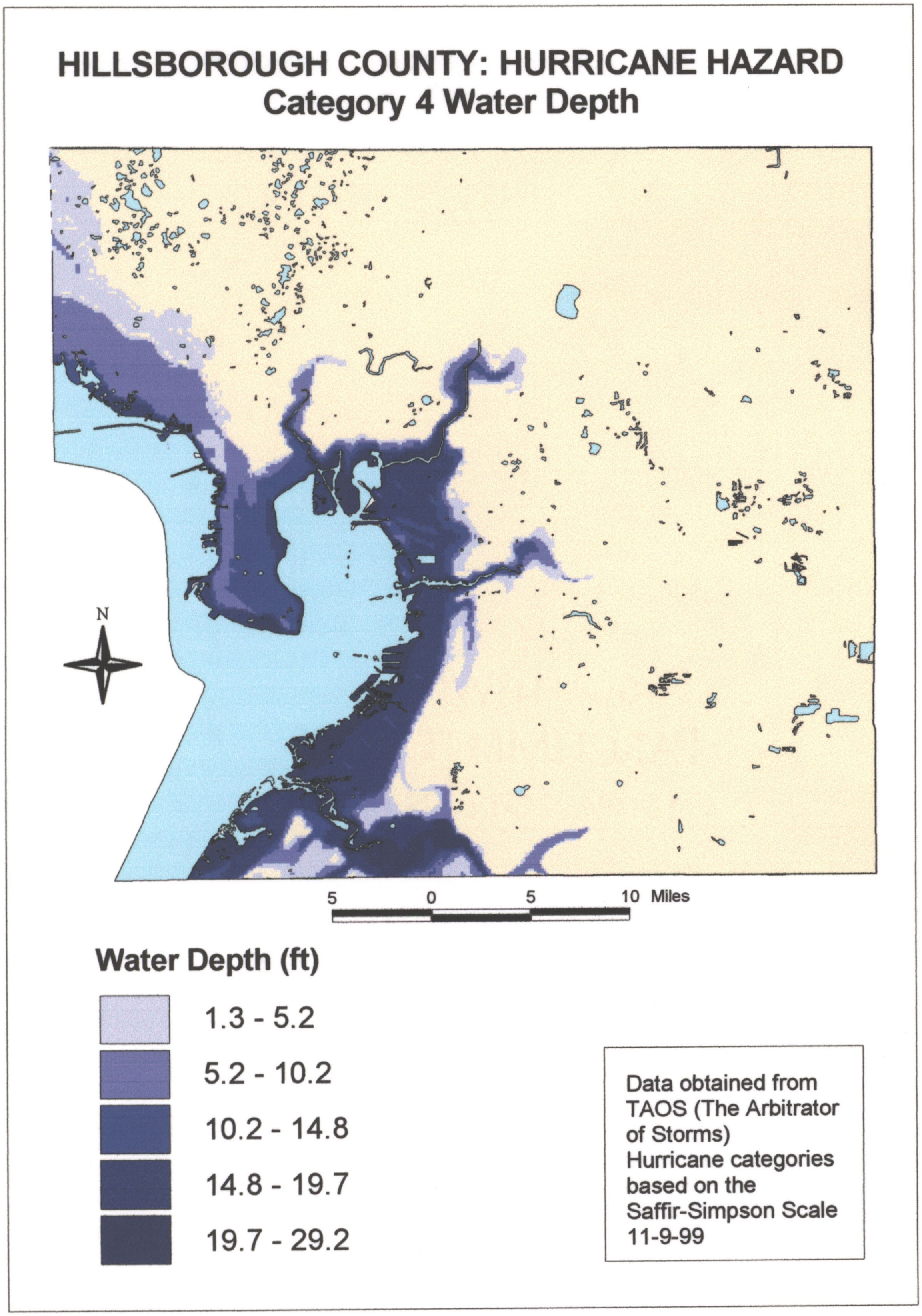

Fig. 22: Hillsborough County - Areas impacted by hurricane category IV water depth greater than one foot.

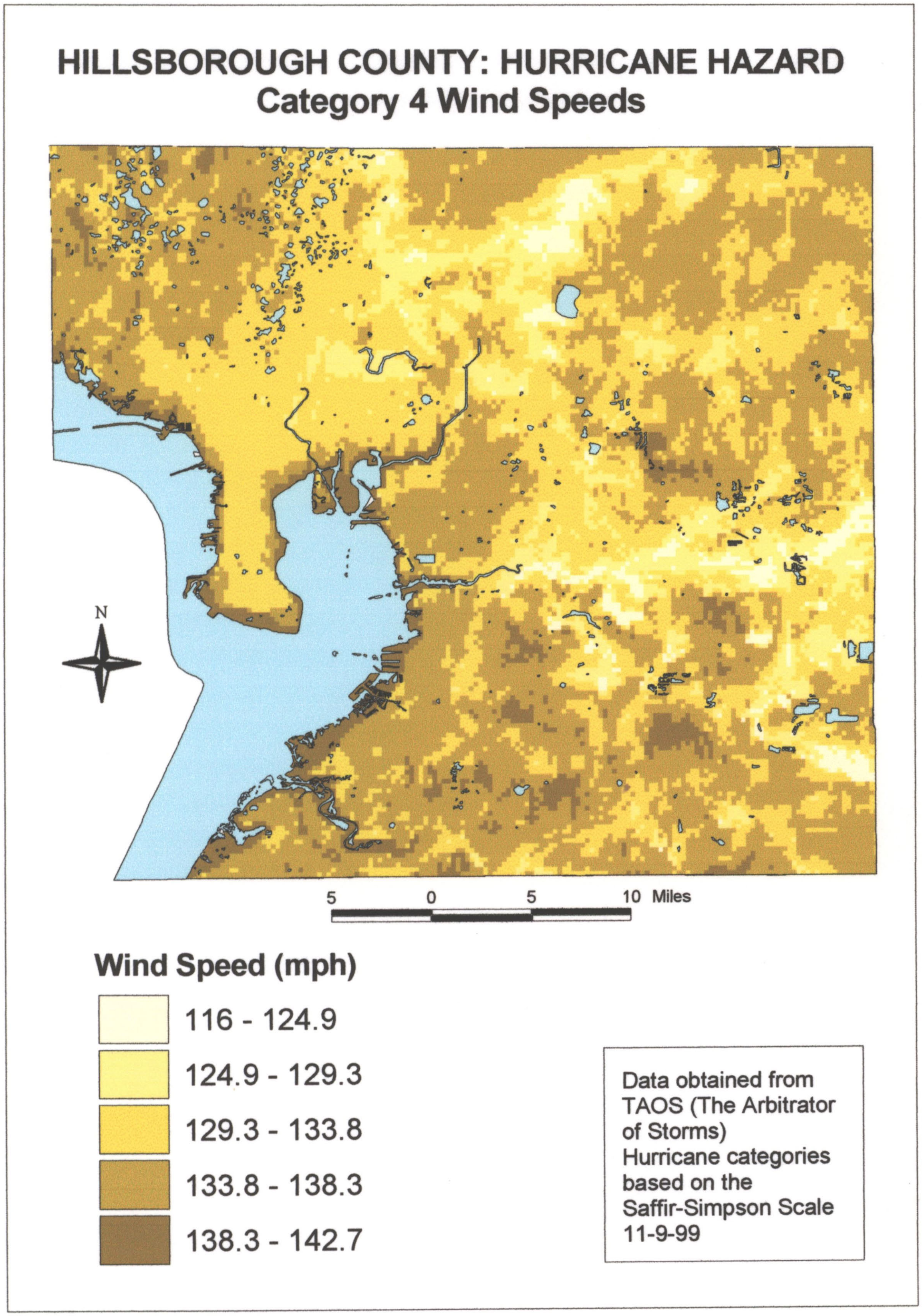

Fig. 23: Hillsborough County - Areas impacted by hurricane category IV winds speeds.

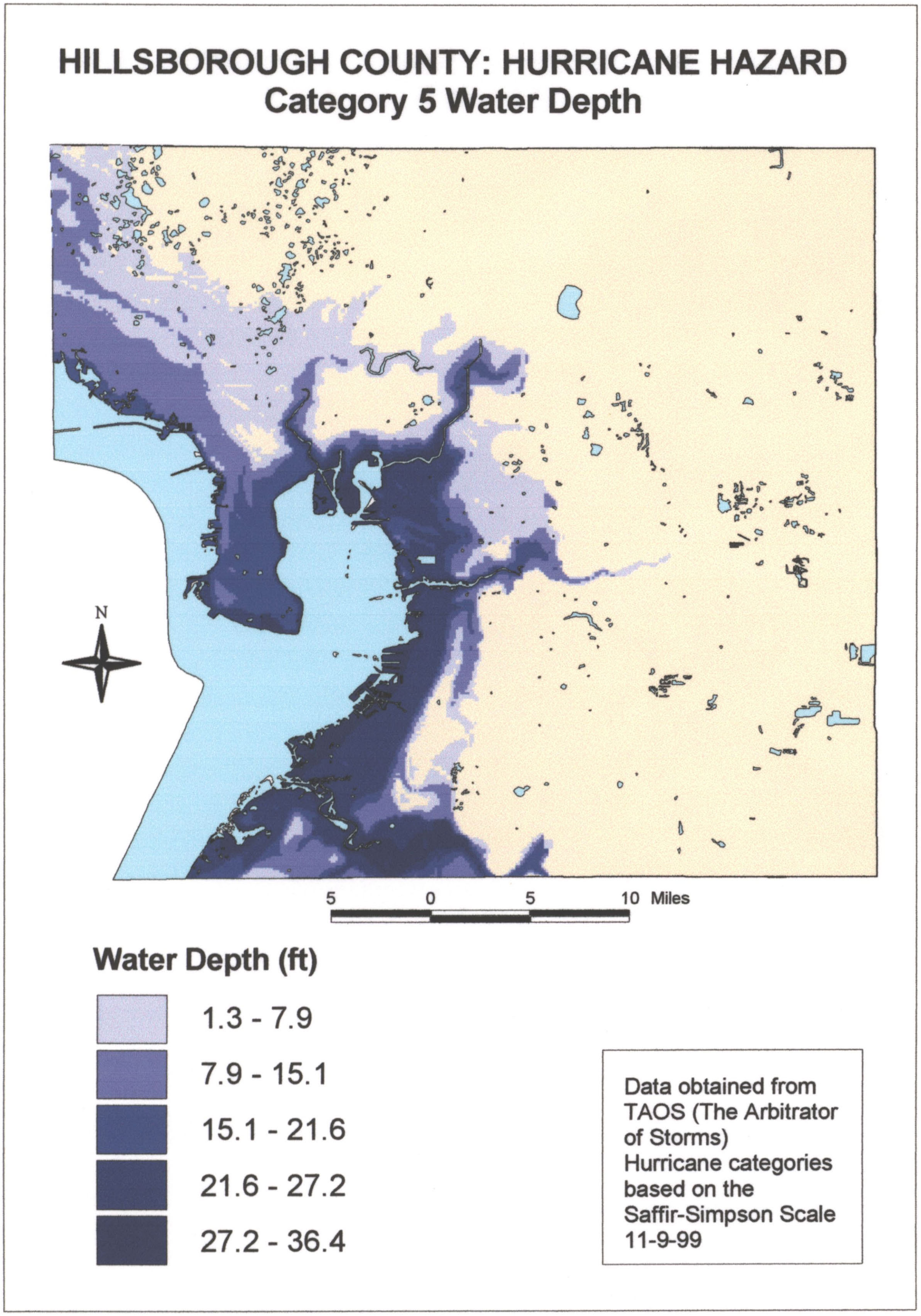

Fig. 24: Hillsborough County - Areas impacted by hurricane category V water depth greater than one foot.

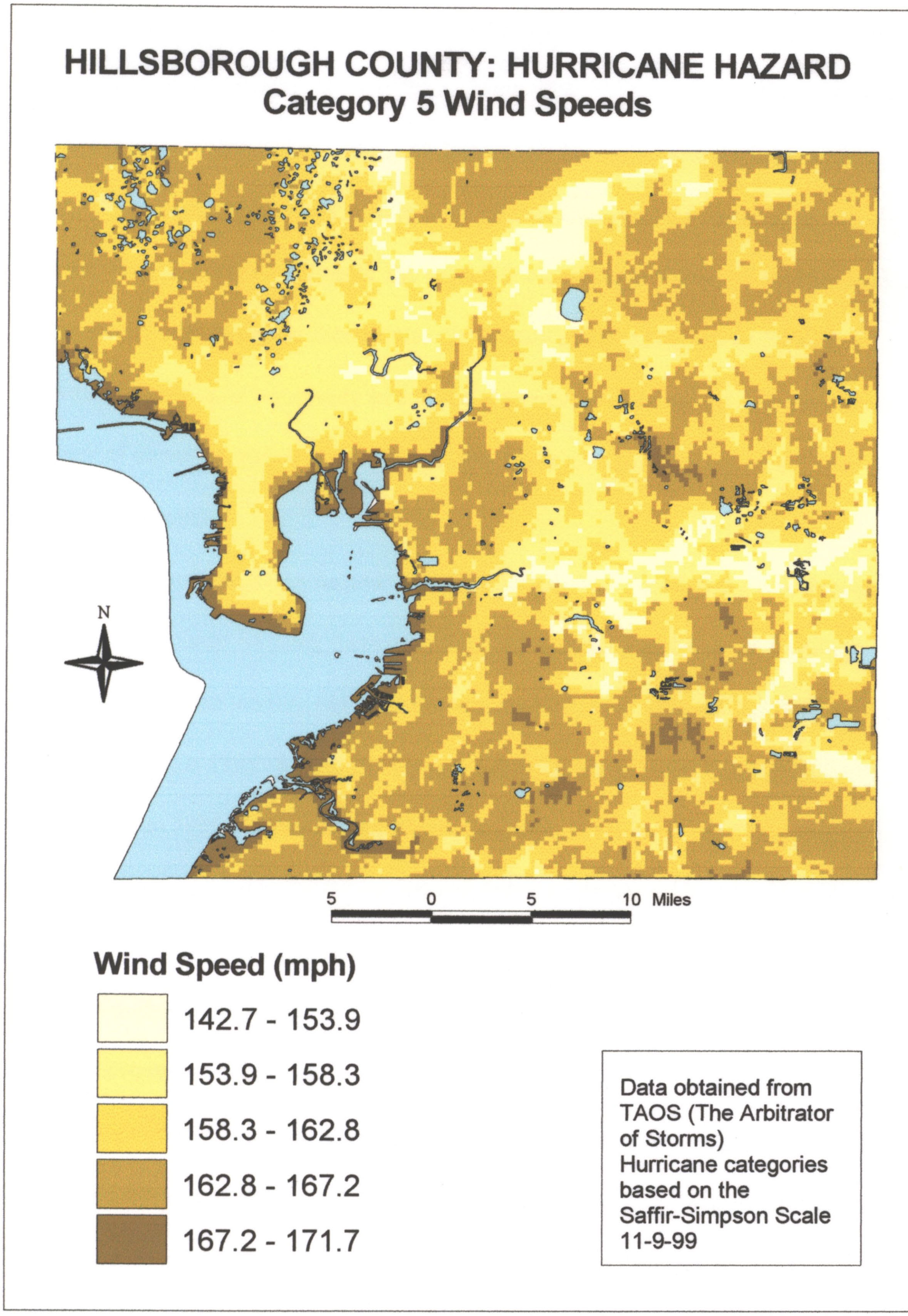

Fig. 25: Hillsborough County - Areas impacted by hurricane category V winds speeds.

The previous figures simply depict areas in the county by the amount of physical hazard that would potentially impact them during each disaster event. These figures act as a first glance of the potential physical destruction that may occur during a hazard event. The county was initially seen to have greater impact on the coast, as previously thought, yet during stronger events, the impact of storm surge and winds reaches much farther inland. Of particular interest was the amount of damaging winds found in the northeastern portion of the county as compared to central Hillsborough. In addition, due to a lack of elevation, storm surge and standing water are found farther inland than originally expected.

Along with the above hazards are other geophysical events that cause damage to Hillsborough County. Among these are tornadoes, sinkholes and riverine flooding. Figure 26 depicts the starting points of every tornado that has affected Hillsborough County from 1950-1995. Figure 27 shows the distribution of sinkholes in Hillsborough County prior to 1995. Figure 28 and Figure 29 delineate the areas of Hillsborough County that would be affected by the 100 and 500 year flood events. Note that the areas affected by the 500 year flood also include those areas affected by the 100 year flood.

Tornadoes, sinkholes and riverine flooding, although not often compared to hurricane events in severity, have a relatively high potential of occurrence in Hillsborough county. Although tornadoes in Florida are relatively small, Hillsborough County has been impacted by at least two every year since 1950. In addition, flood events equal to and greater than the 100 year event have the potential to impact large portions of the county, as seen in Figure 28. Sinkholes also pose a threat to development within the County because of the underlying karst topography.

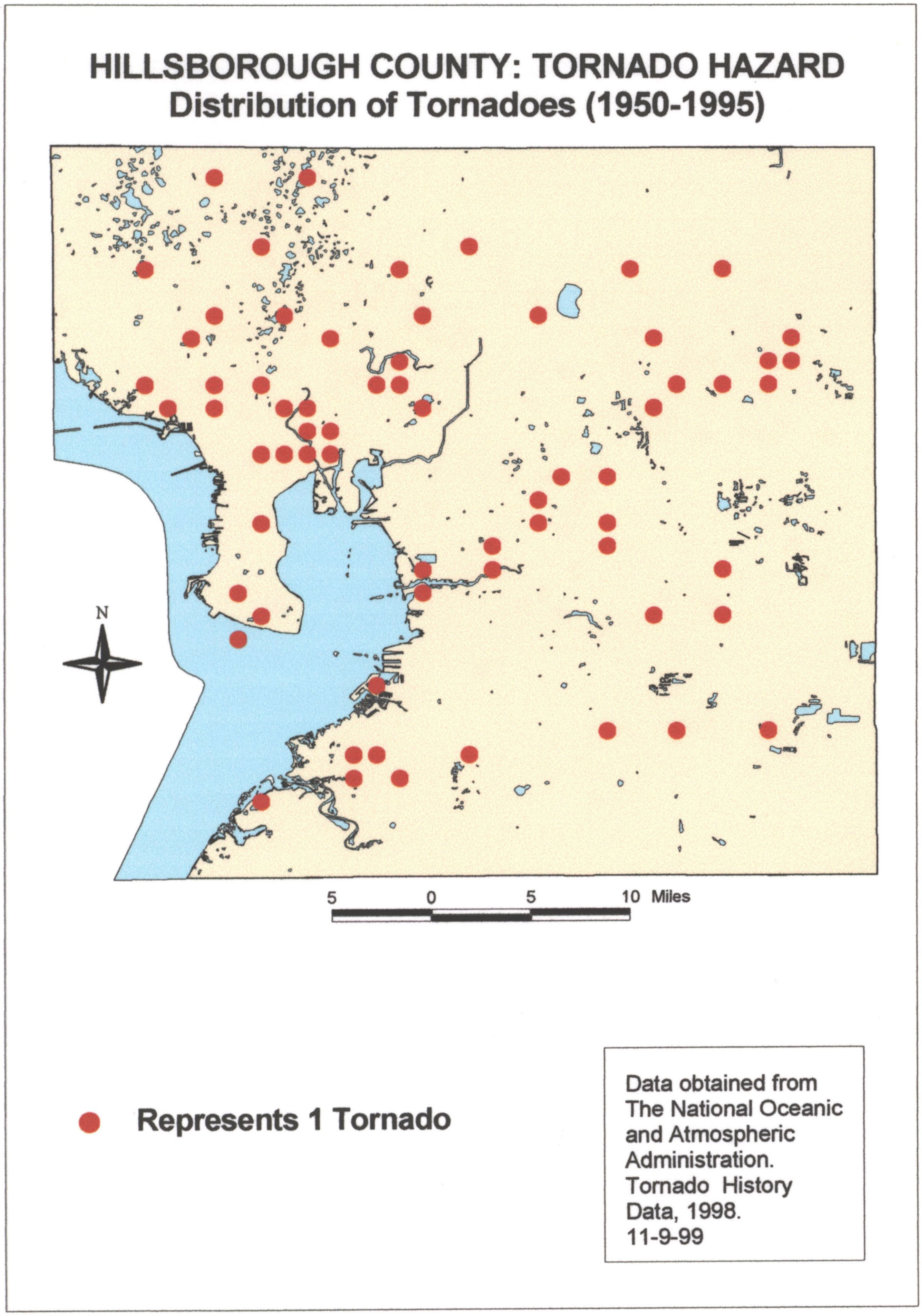

Fig. 26: Hillsborough County - Distribution of Tornadoes (1950 - 1995).

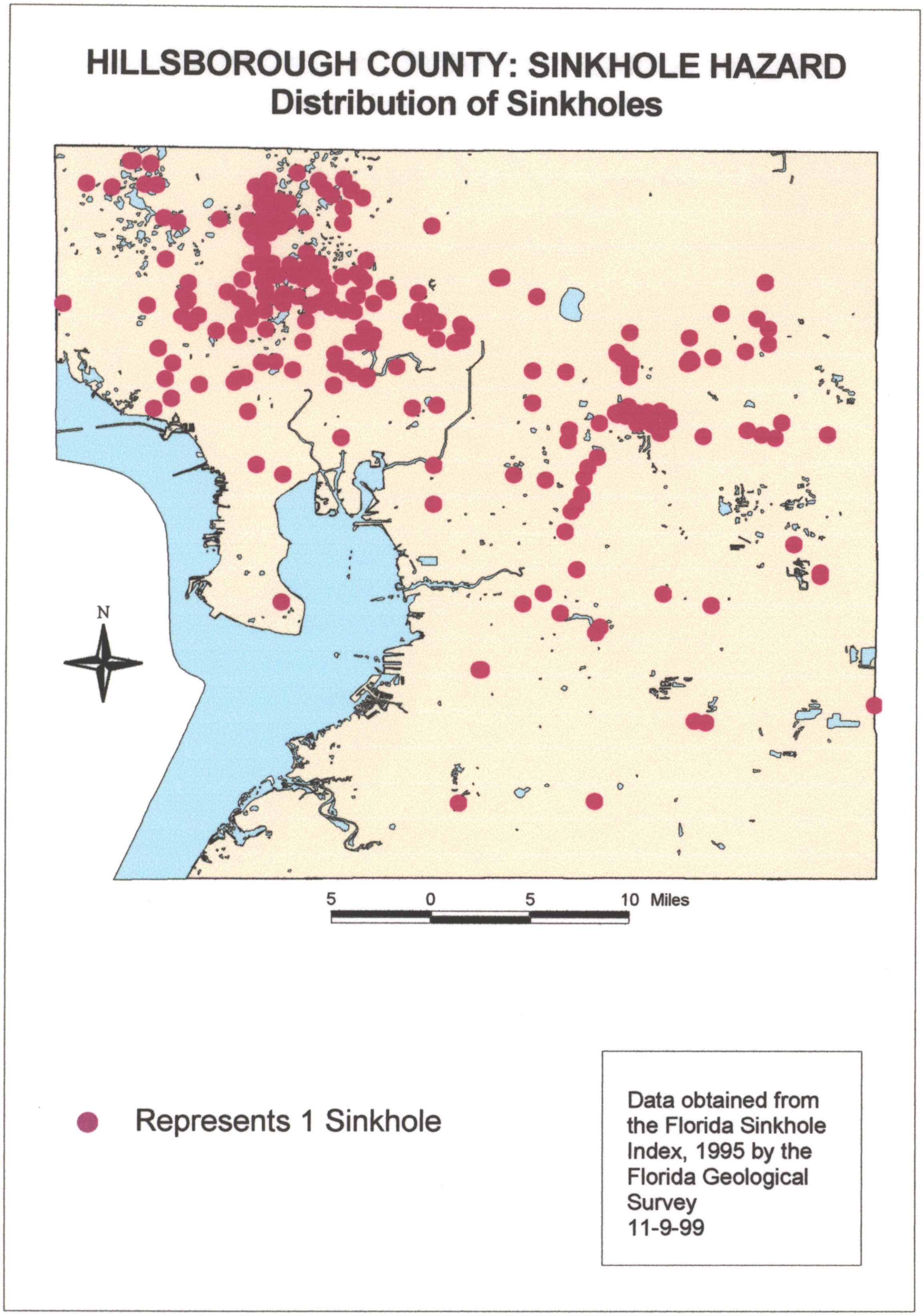

Fig. 27: Hillsborough County - Distribution of Sinkholes.

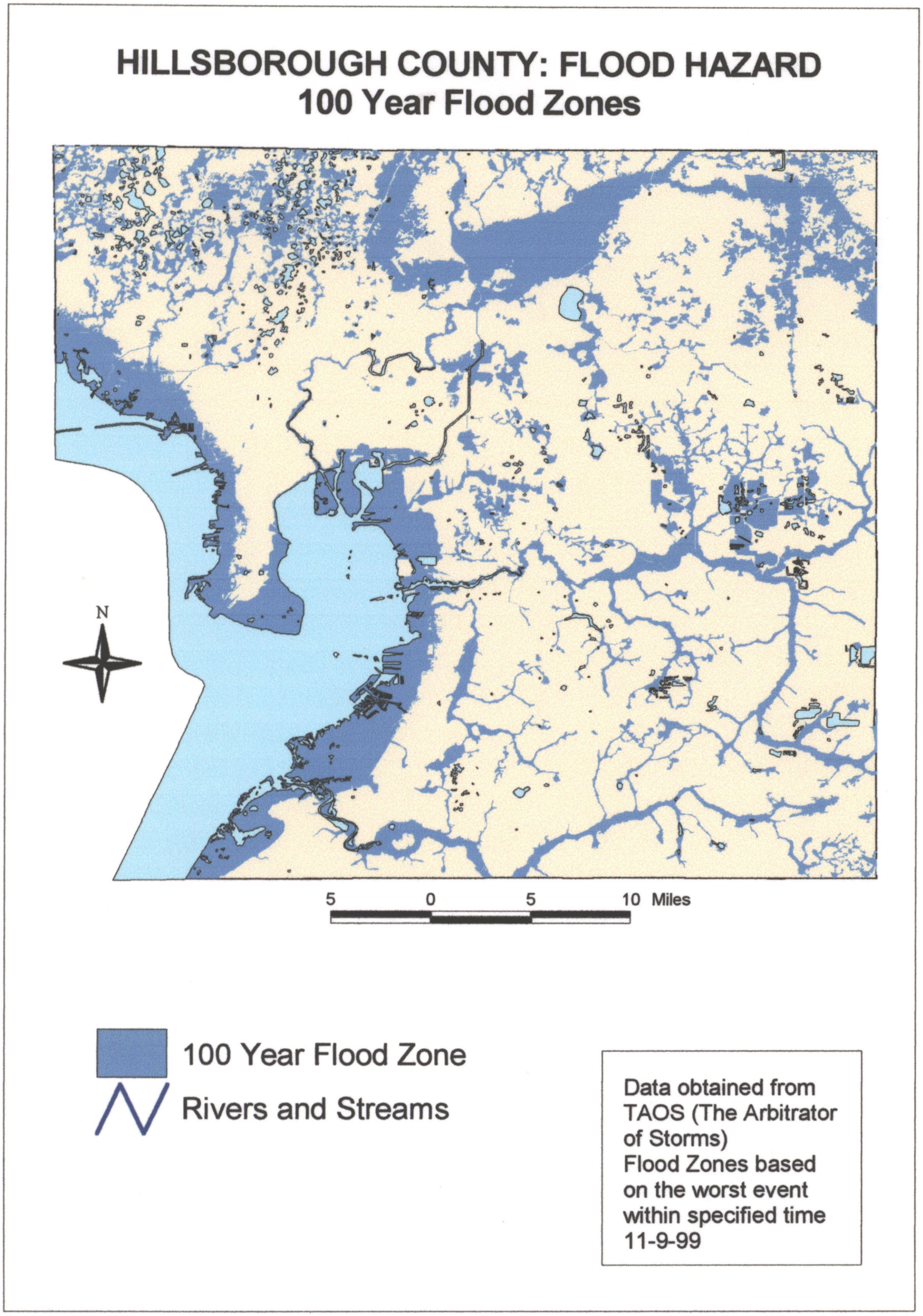

Fig. 28: Hillsborough County - Areas impacted by the 100-year flood event.

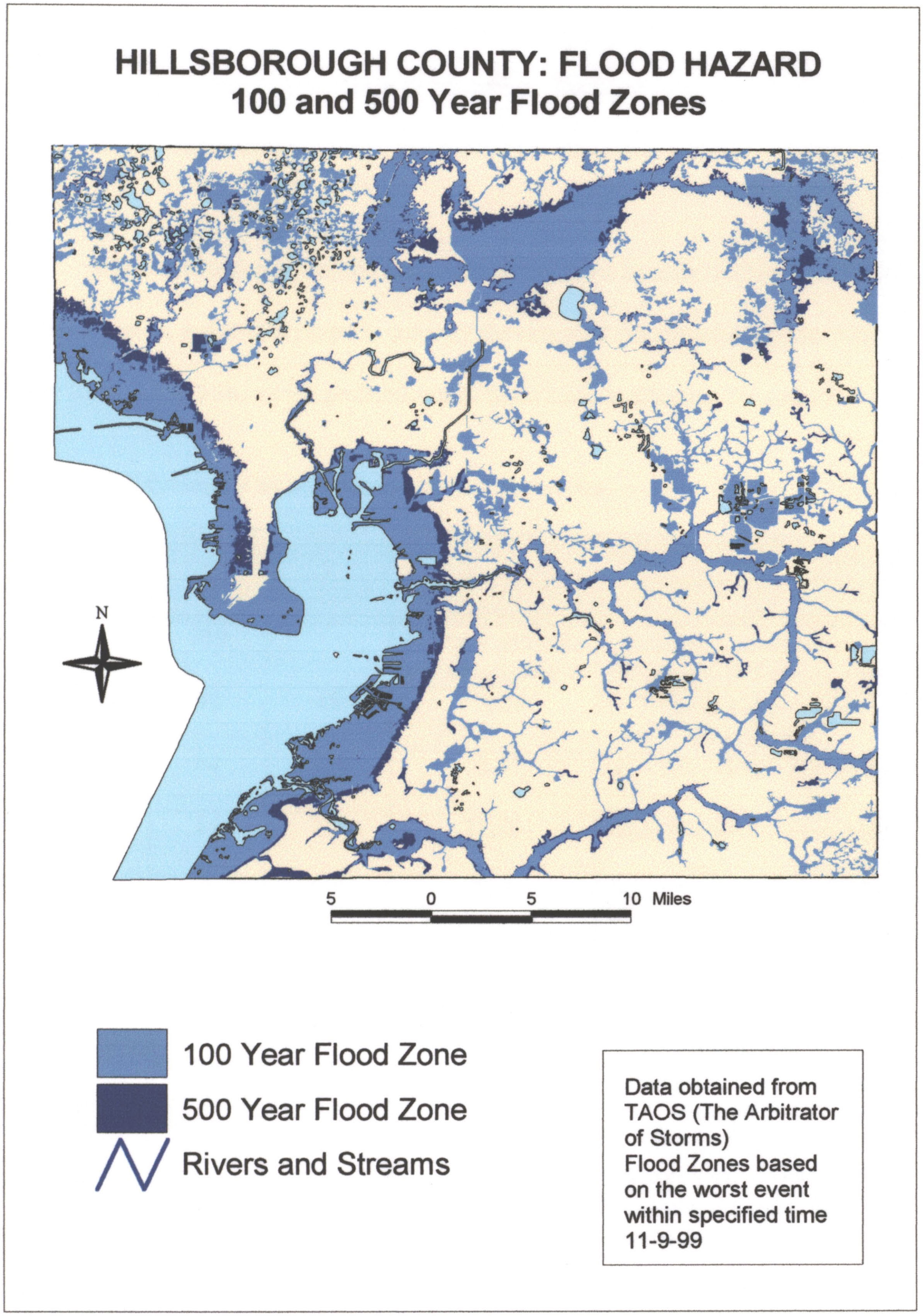

Fig. 29: Hillsborough County - Areas impacted by the 500-year flood event.

As seen in Figure 27, there are numerous portions of the county that are under a constant state of threat from sinkhole development. These areas include the University of South Florida, the Carrollwood area, and much of north central and central Hillsborough County.

While visual displays of the areas affected by these hazards is a beneficial aspect of this research, it does not properly quantify the extent of the potential hazard. Along these lines, Table 3 shows the probabilities of these hazards affecting the county.

Table 3: Hillsborough County - hazard event probabilities

Hazard	Number of Events	Years in Record	Hazard Frequency % chance/year	Data Source
Sinkhole	319		0.1 new sinkhole per square meter	Sinkhole Development in Hillsborough County, 1996
Tornado	90	45	100.00	Tornado History Data, NOAA, 1998
Tropical Storm	60	112	53.57	SLOSH, NHC, 1886-1998
Hurricane Cat 1	14	112	12.50	SLOSH, NHC, 1886-1998
Hurricane Cat 2	8	112	7.14	SLOSH, NHC, 1886-1998
Hurricane Cat 3	6	112	5.36	SLOSH, NHC, 1886-1998
Hurricane Cat 4	0	112	0.20	*Hazardousness of Place* Montz, 2000
Hurricane Cat 5	0	112	0.20	*Hazardousness of Place* Montz, 2000
100 Year Flood	*	*	1.00	Federal Emergency Management Agency, 1995
500 Year Flood	*	*	0.20	Federal Emergency Management Agency, 1995

Locational Risk Assessment

Often, the need for esthetically pleasing, natural looking back yards and neighborhoods competes with nature's ability to defend itself against naturally occurring hazards. This problem persists along Florida's coastlines and rivers causing potential hazards to become disasters because of over development and poor planning. Hillsborough County is a prime example of this problem. Over population and poor construction, along with environmental destruction are putting more and more people and land at risk of being affected by natural hazards. Populations along the barrier islands and river basins often do not see natural hazards as potential disasters. Because of this, the areas that would be most affected by natural hazards are the coastal zones and the river basins, although no area is immune to all hazards.

Research showed that hurricanes and the individual hazards that comprise them are the most devastating events that have the potential to strike Hillsborough County. The destruction from a hurricane event does not come from any single factor, but rather a series of characteristics. These include storm surge, water depth and wind speed. Note, however, that the use of census blocks does not mean that everyone living within these areas are equally at risk to the devastating effects of naturally occurring hazards.

Figure 30 delineates the census blocks of Hillsborough County that would be affected by tropical storm wind speeds. These winds, in excess of thirty-nine miles per hour, would encompass 784 census blocks and would affect approximately 865,402 people. Figure 31 displays the census blocks of Hillsborough County that would be affected by tropical storm water depth. Tropical storm water depth greater than one foot

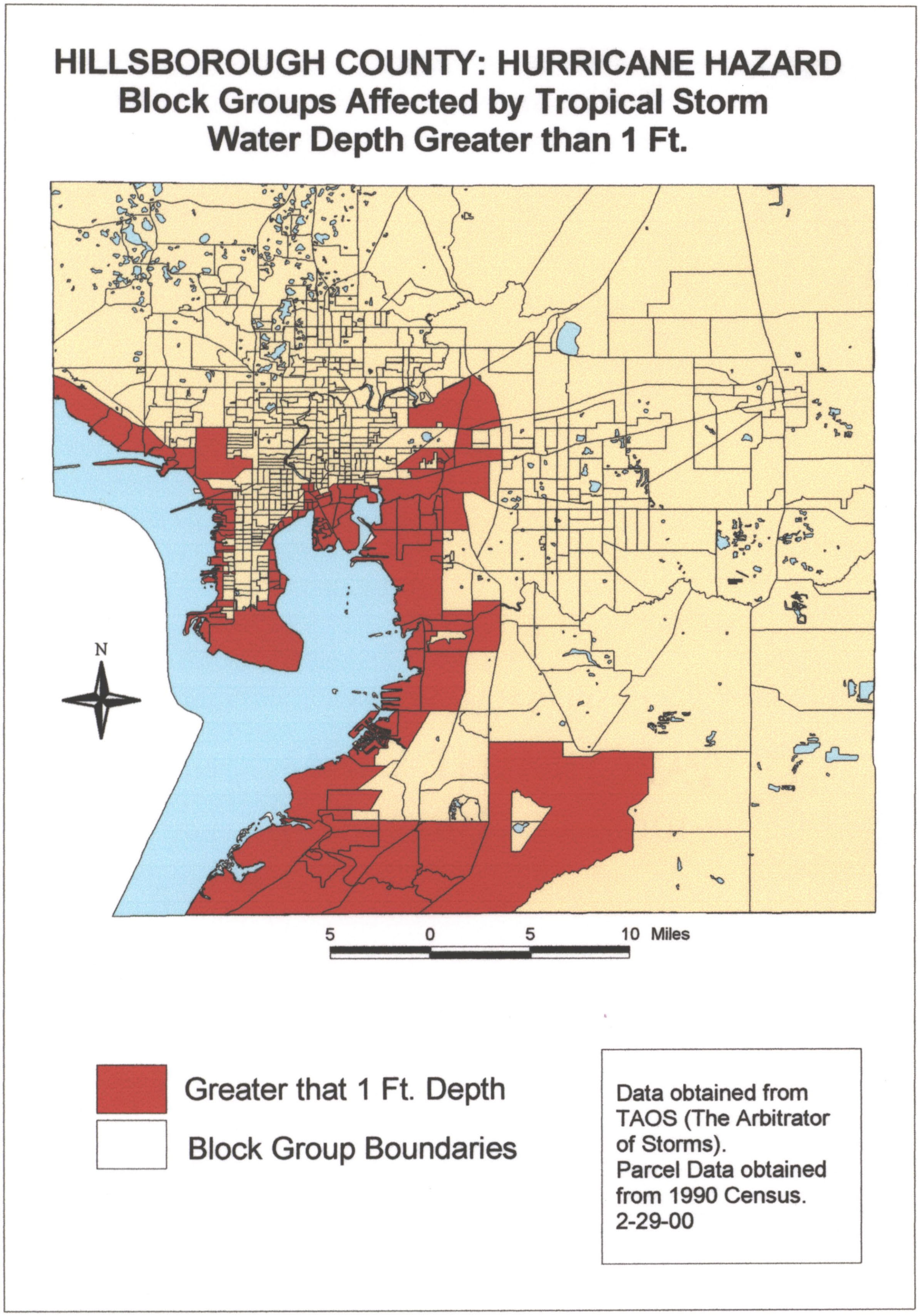

Fig. 30: Hillsborough County - Census blocks affected by tropical storm water depth greater than one foot.

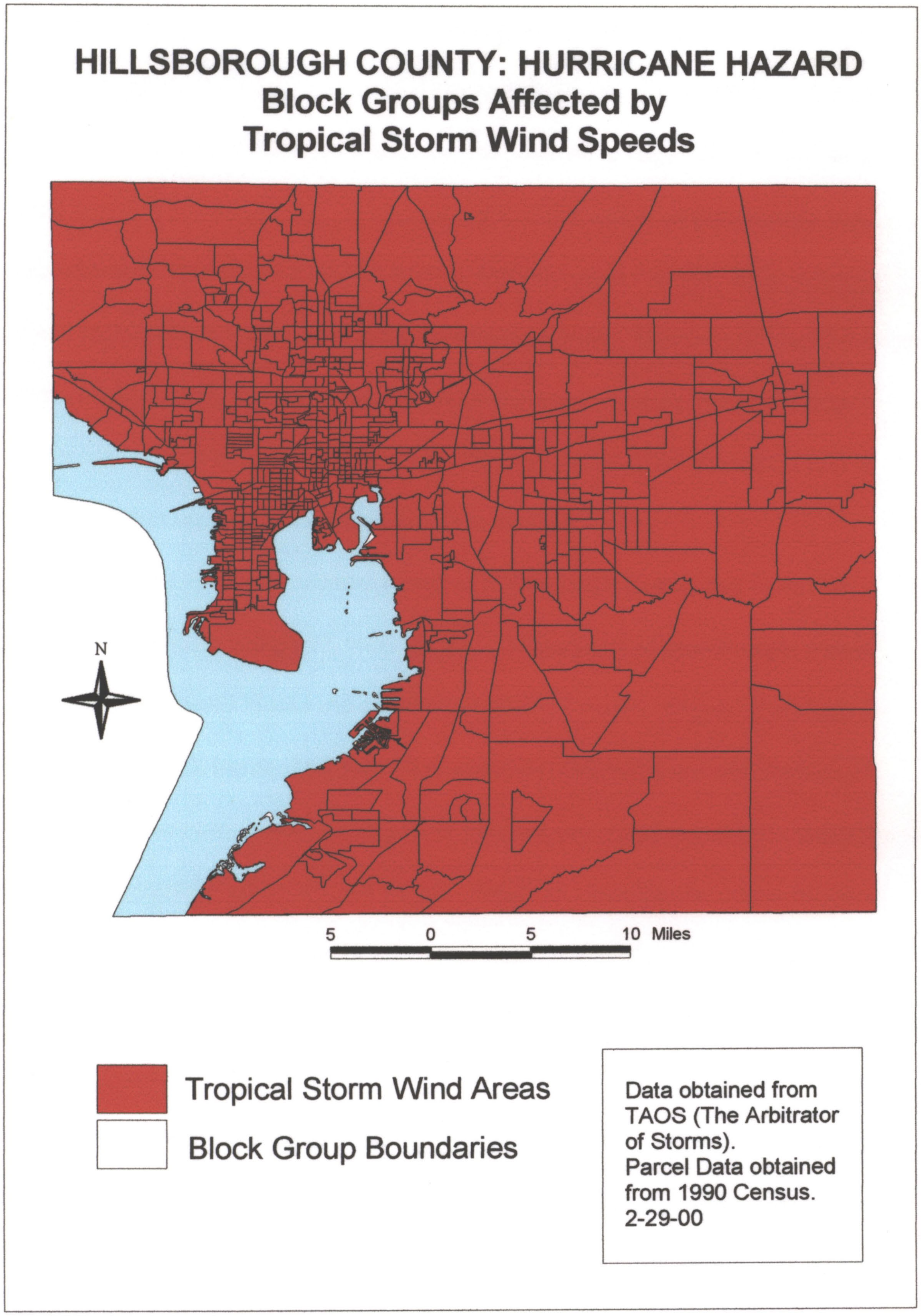

Fig. 31: Hillsborough County - Census blocks affected by tropical storm wind speeds.

deep could encompass 140 census blocks and could potentially affect 133,558 people. Figure 32 depicts the census blocks of Hillsborough County that would be affected by tropical storm surge. This surge could have the potential to engulf 202 census blocks and could inundate 238,832 people. A tropical event of this nature would normally impact an area with pouring rain and gusts that could potentially cause damage. Most structures would withstand wind speeds produced by a tropical storm. However, tropical storms are often poorly defined, tending to move more slowly and thus could potentially drop feet of rain in any location within the storm track. This inundation could potentially lead to more flood damage than actual hurricane force damage.

Figure 33 depicts the census blocks of Hillsborough County that would be affected by hurricane category I wind speeds. Category I wind speeds might possibly encompass 741 census blocks and could effect 826,434 people. Figure 34 portrays the census blocks of Hillsborough County that would be affected by hurricane category I water depth. Category I water depth greater than one foot could engulf 233 census blocks and could potentially affect 207,334 people. Figure 35 visualizes the census blocks of Hillsborough County that would be affected by hurricane category I storm surge. Category I surge could cause flooding to 223 census blocks and potentially could impact 275,331 people. A hurricane event of this magnitude normally produces no real damage to buildings, with the exception of unanchored mobile homes. Some coastal and road flooding can be expected with an event of this magnitude due to a storm surge of up to 5 feet in some areas. An event of this category will necessitate evacuation of coastal areas and some low lying inland areas.

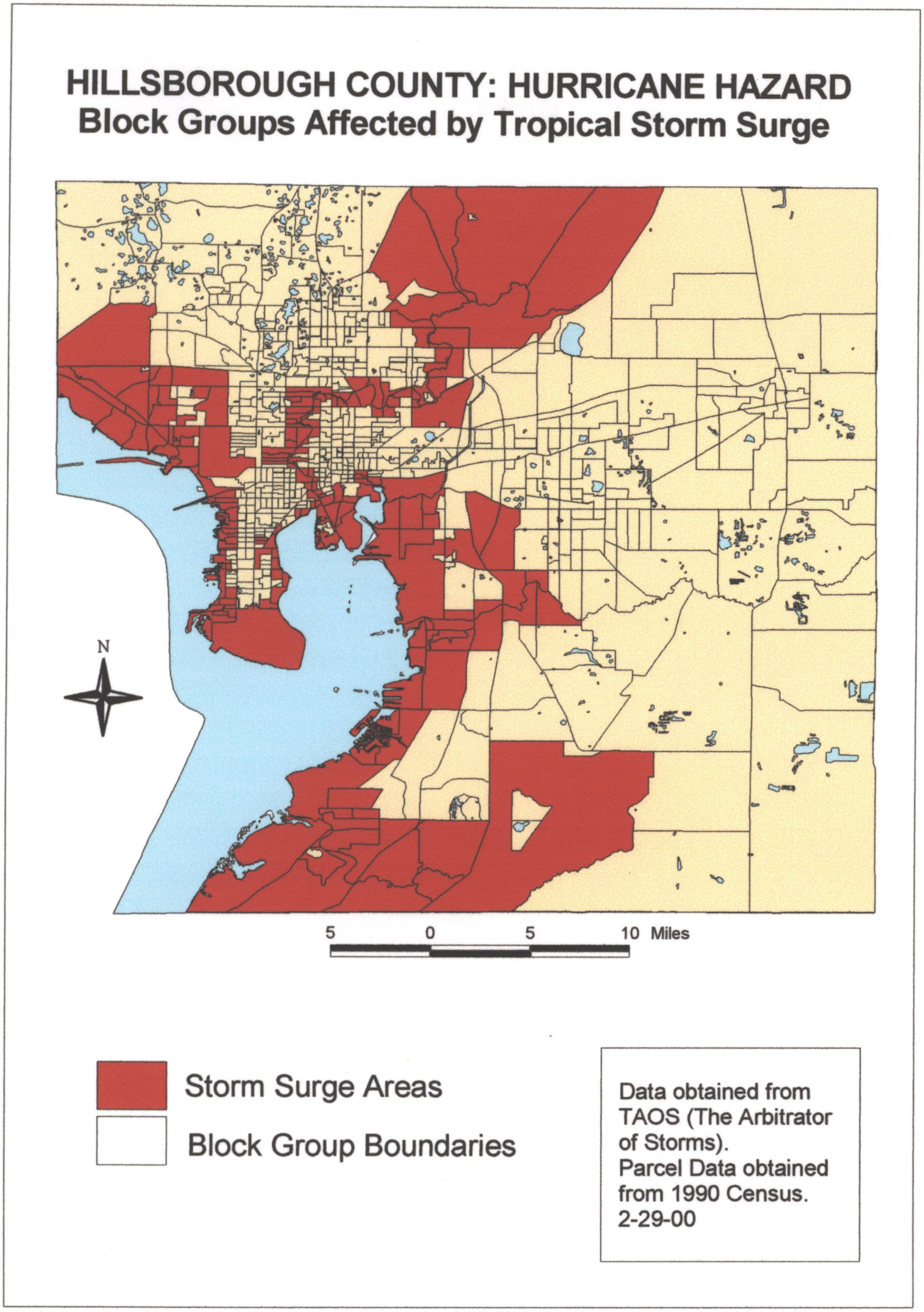

Fig. 32: Hillsborough County - Census blocks affected by tropical storm surge.

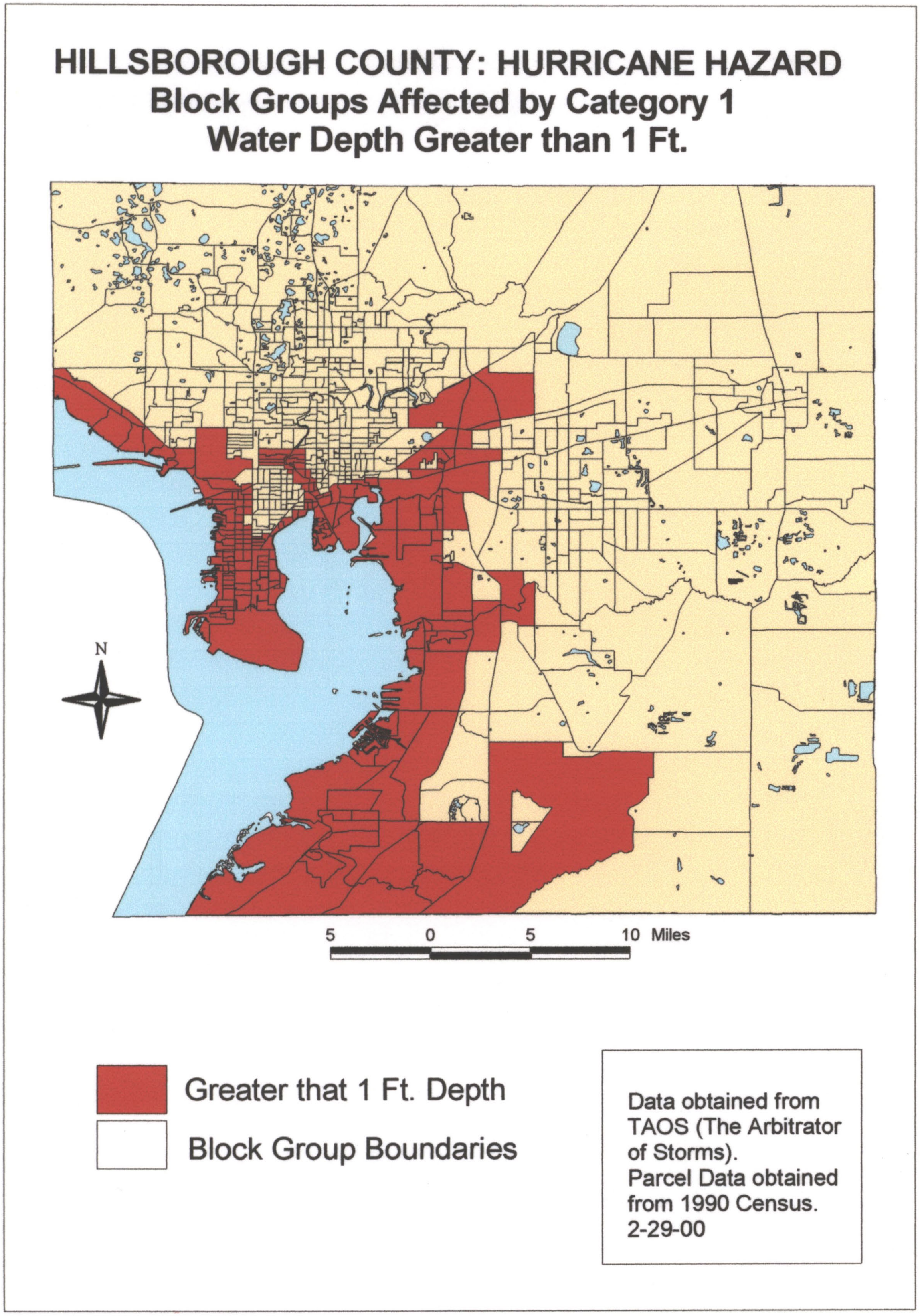

Fig. 33: Hillsborough County - Census blocks affected by hurricane category I water depth greater than one foot.

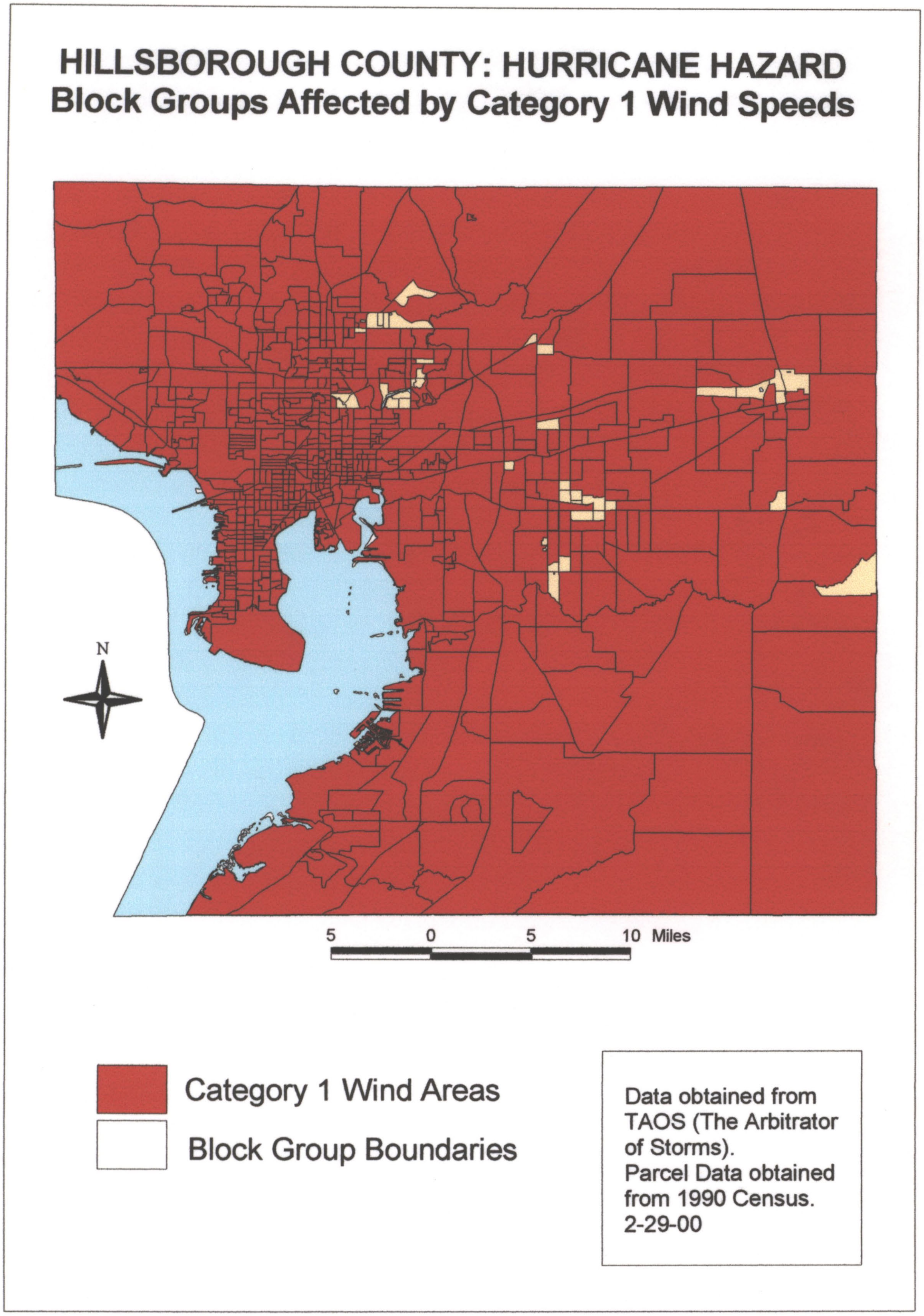

Fig. 34: Hillsborough County - Census blocks affected by hurricane category I wind speeds.

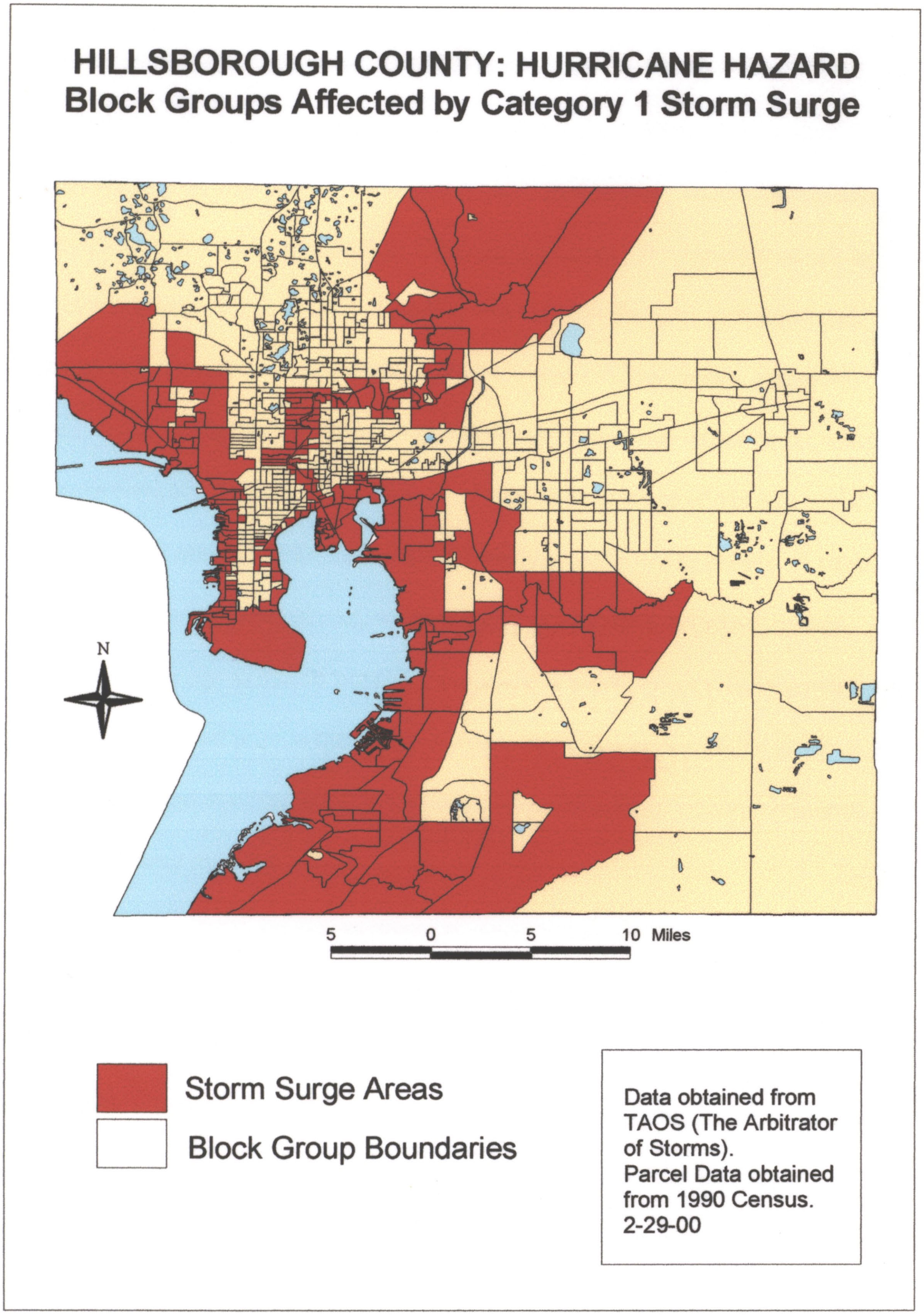

Fig. 35: Hillsborough County - Census blocks affected by hurricane category I storm surge.

Figure 36 displays the census blocks of Hillsborough County that would be affected by hurricane category II wind speeds. Winds greater than 96 miles per hour would potentially envelop 236 census blocks and could impact as many as 294,261 people. Figure 37 depicts the census blocks of Hillsborough County that would be struck by hurricane category II water depth. Standing water greater than one foot deep could inundate 288 census blocks and could possibly swamp 259,588 people. Figure 38 visually describes the census blocks of Hillsborough County that would be impacted by hurricane category II storm surge. A wave of water from a storm of this size could flooding to 285 census blocks and could potentially engulf 319,582 people. A category II hurricane will cause potential roof, window and door damage to all structures and considerable damage to mobile homes. Evacuation of coastal areas will be necessary as these areas will flood prior to the arrival of the center of the storm. Inland flooding due to storm surge and standing water will prohibit immediate return to many structures during post event recovery.

Figure 39 shows the census blocks of Hillsborough County that would be affected by hurricane category III wind speeds. Winds over 111 miles per hour could howl through 763 census blocks and might impact as many as 846,629 people. Figure 40 displays the census blocks of Hillsborough County that would be affected by hurricane category III water depth. Water greater than one foot deep could potentially flood 334 census blocks and could affect 309,257 people. Figure 41 depicts the census blocks of Hillsborough County that would be inundated by hurricane category III storm surge. This wave could potentially engulf 322 census blocks and could affect 349,803 people.

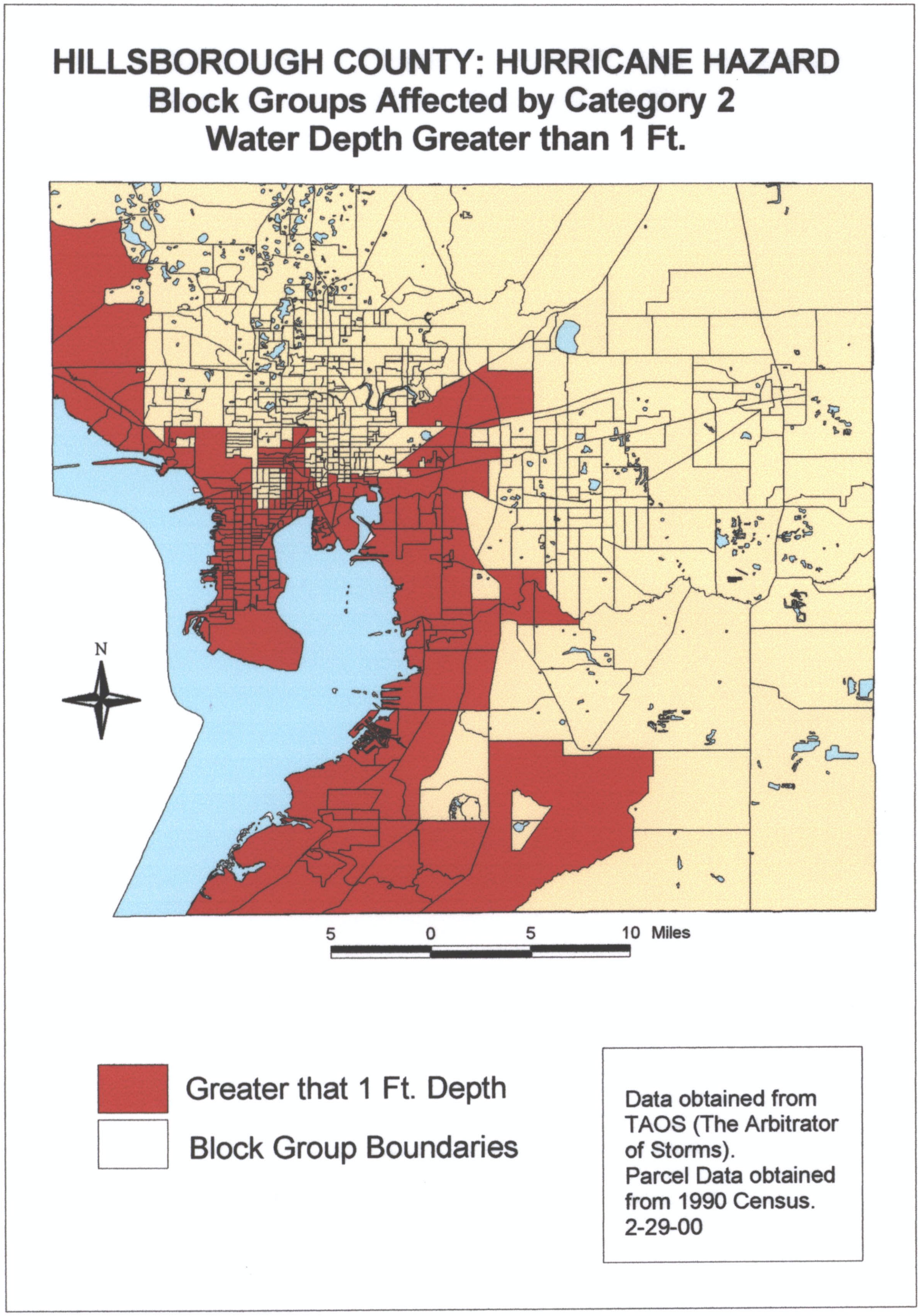

Fig. 36: Hillsborough County - Census blocks affected by hurricane category II water depth greater than one foot.

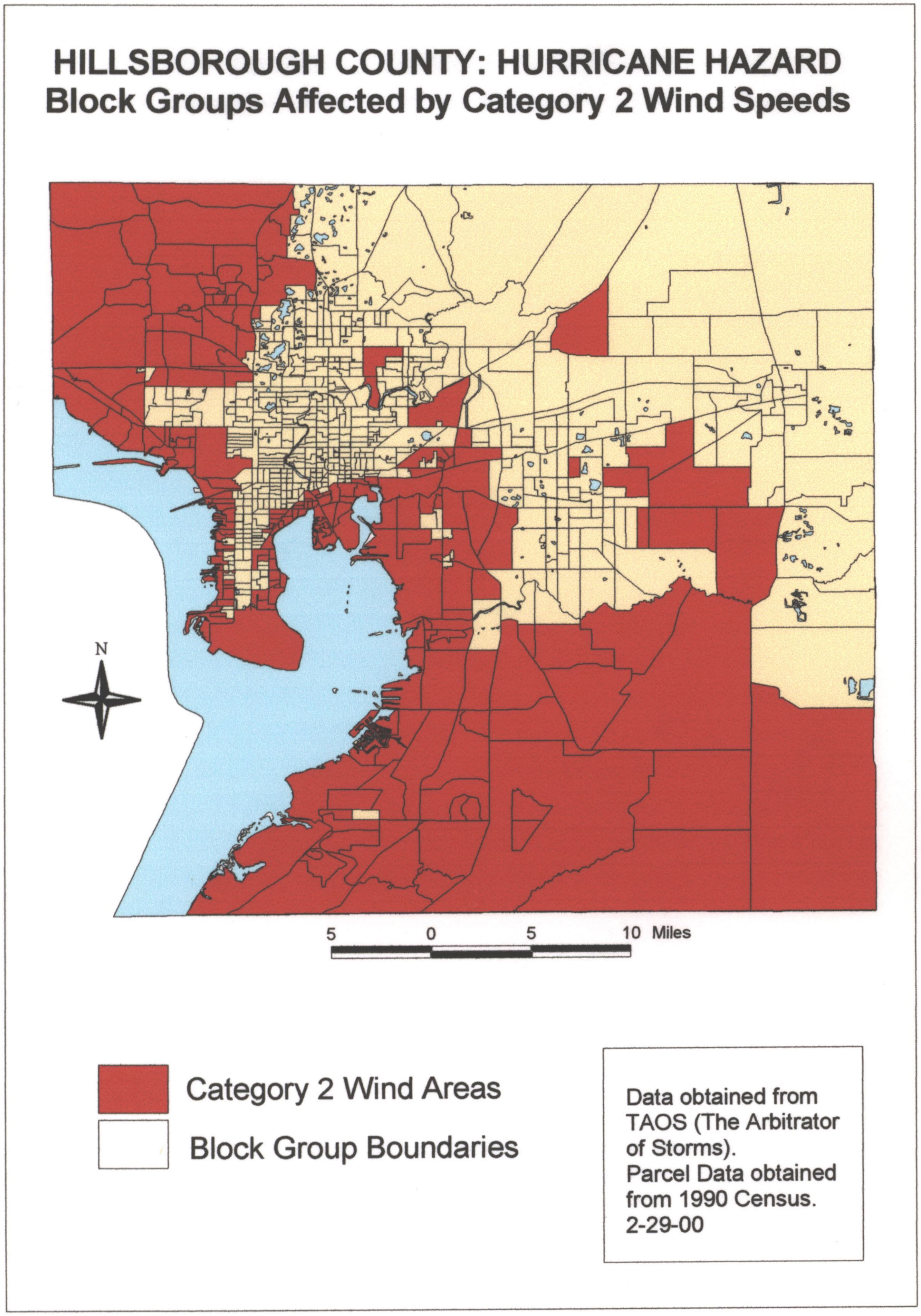

Fig. 37: Hillsborough County - Census blocks affected by hurricane category II wind speeds.

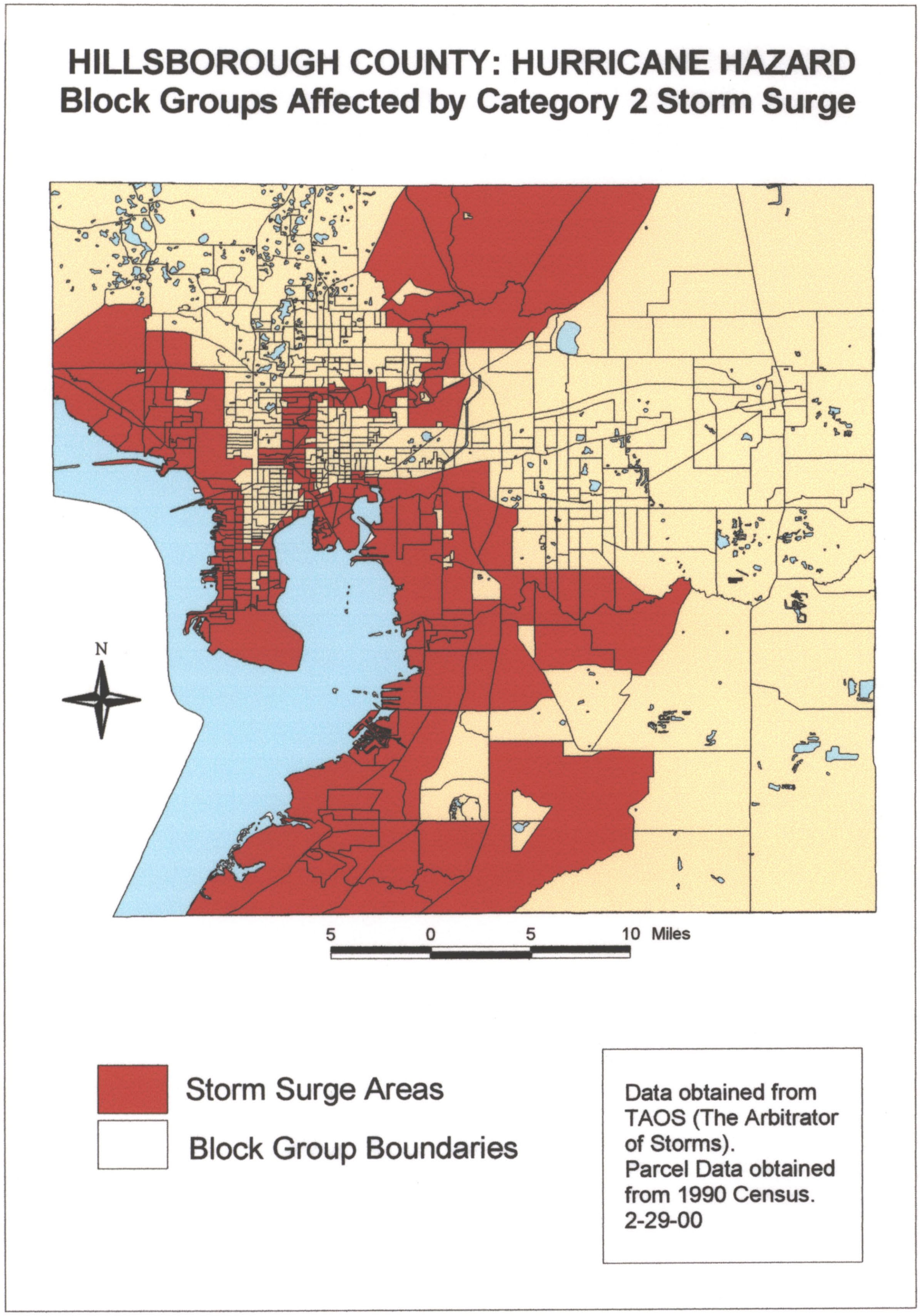

Fig. 38: Hillsborough County - Census blocks affected by hurricane category II storm surge.

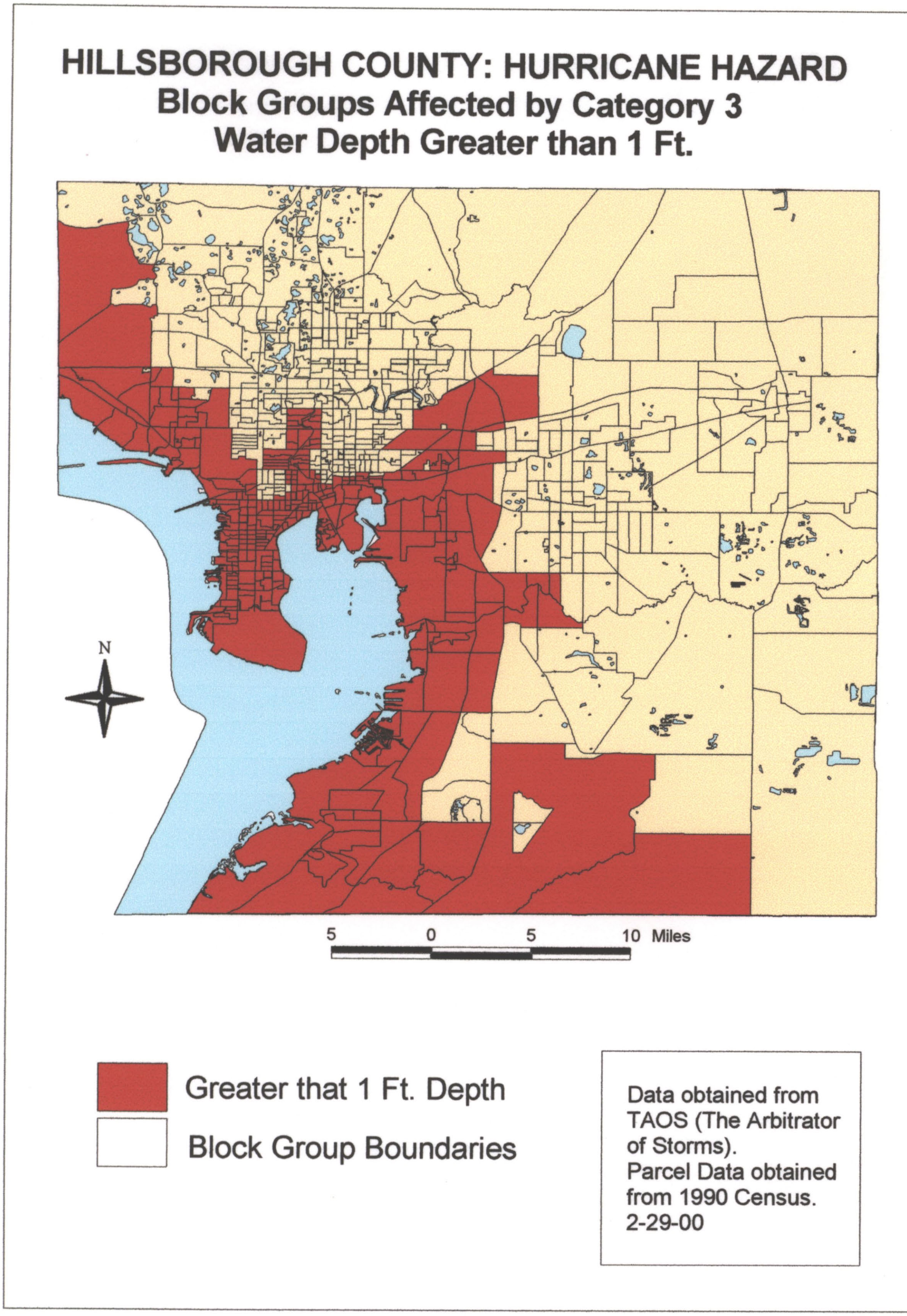

Fig. 39: Hillsborough County - Census blocks affected by hurricane category III water depth greater than one foot.

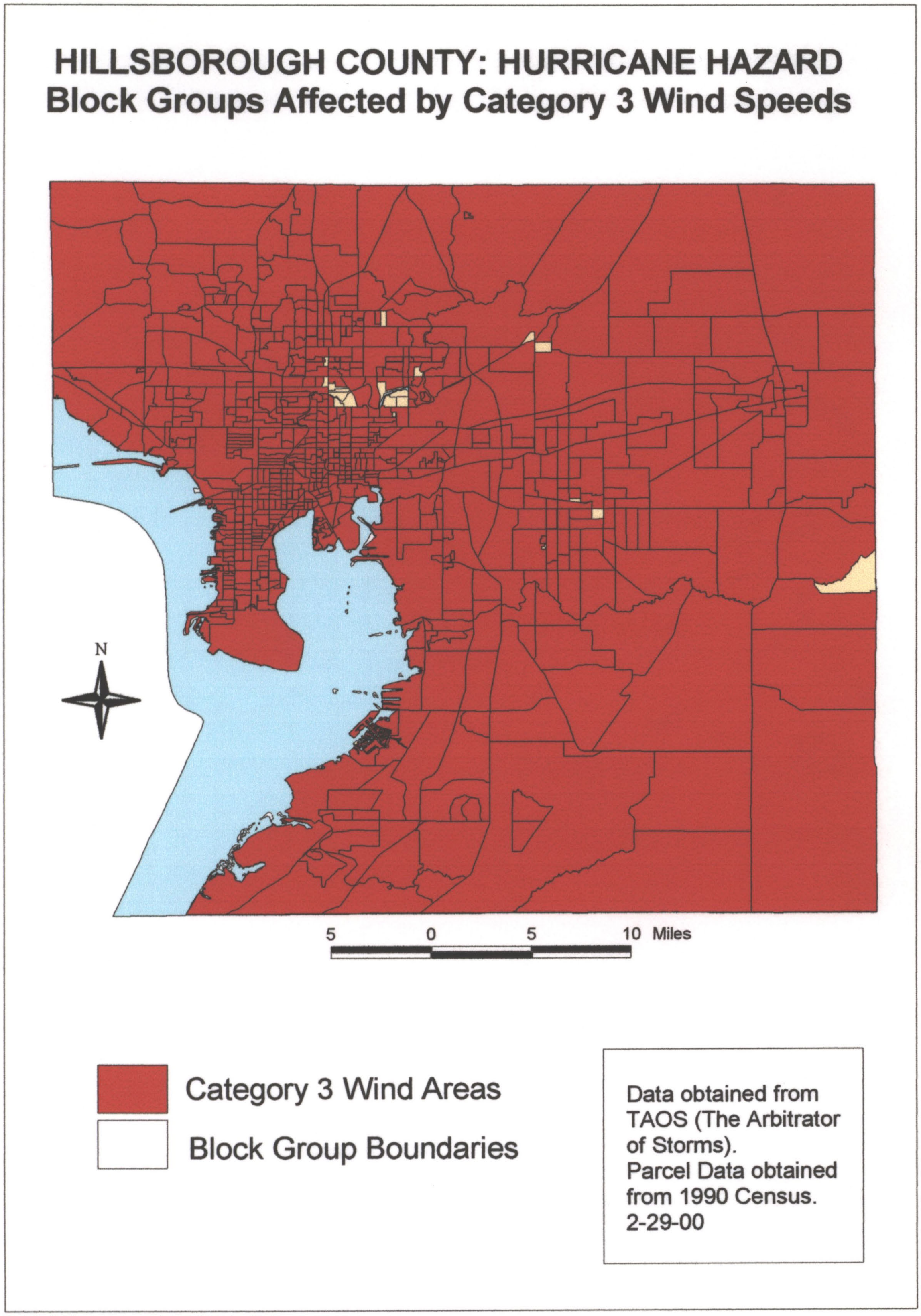

Fig. 40: Hillsborough County - Census blocks affected by hurricane category III wind speeds.

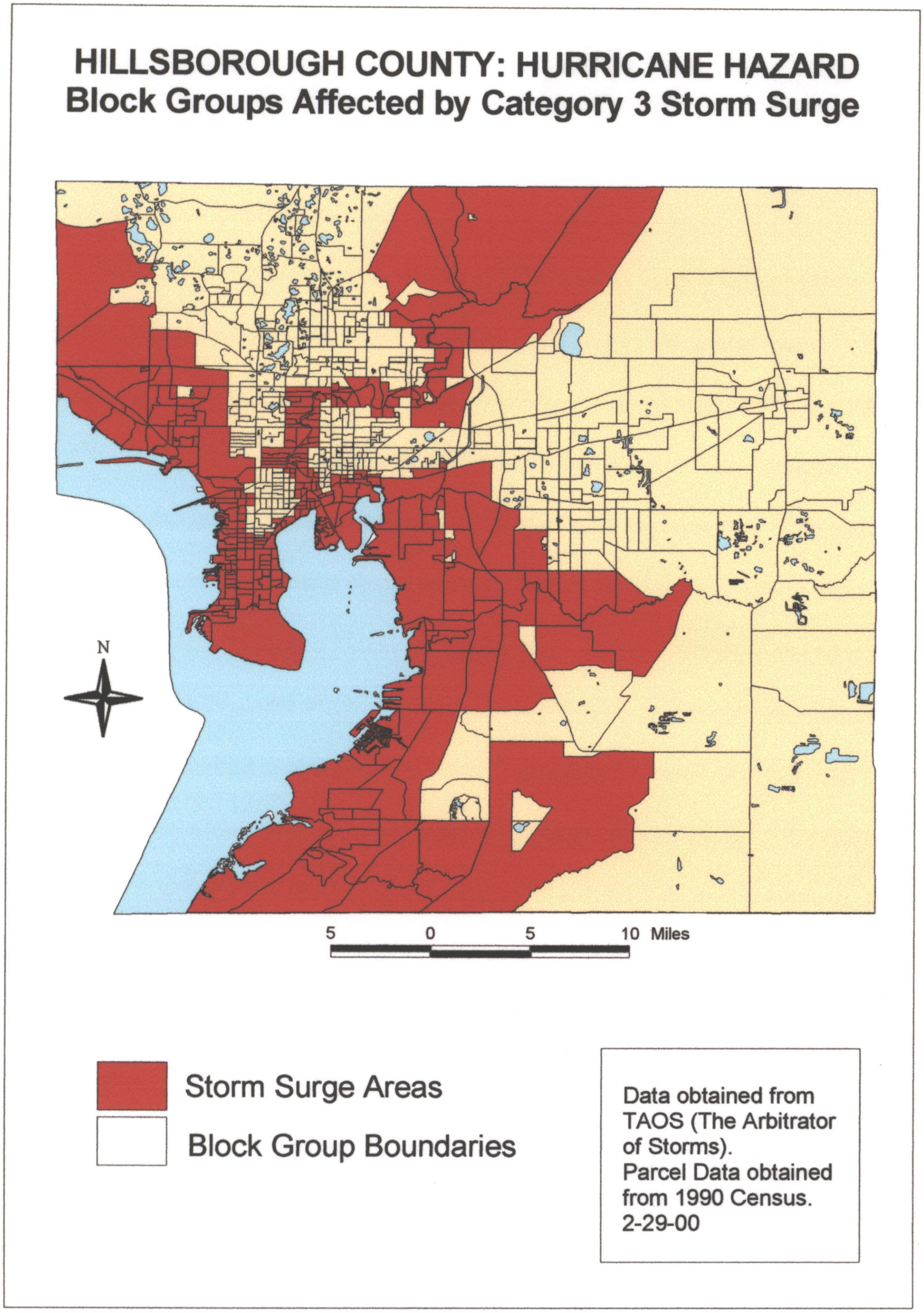

Fig. 41: Hillsborough County - Census blocks affected by hurricane category III storm surge.

An event of this magnitude will leave some people without homes, and others with substantial damage to residences. Most mobile homes will be destroyed during a category III hurricane event. Inland flooding can be expected at least eight miles from the coast during an event of this magnitude.

Figure 42 portrays the census blocks of Hillsborough County that would be impacted by hurricane category IV wind speeds. This flow of air, greater than 131 miles per hour could possibly encompass 775 census blocks and could affect 857,028 people, or almost the entire county. Figure 43 represents the census blocks of Hillsborough County that could be deluged by hurricane category IV water depth over one foot. This water could possibly cover 382 census blocks and might affect as many as 370,085 people. Figure 44 delineates the census blocks of Hillsborough County that would be impacted by hurricane category IV storm surge. This wall of water has the potential to inundate 377 census blocks and could swamp 388,690 people. Category IV hurricanes will cause complete roof structure failures on most small residences. In addition, an event of this size will flood terrain lower than 10 feet above sea level and cause massive damage to lower levels of structures near the shore. Inland areas as far as six miles will be evacuated during a category IV hurricane event.

Figure 45 depicts the census blocks of Hillsborough County that would be affected by hurricane category V wind speeds. These winds, in excess of 155 miles per hour would blow through 782 census blocks and affect 864,224 people. Figure 46 shows the census blocks of Hillsborough County that would be impacted by hurricane category V water depth greater than one foot deep. This water might flow into as many as 556

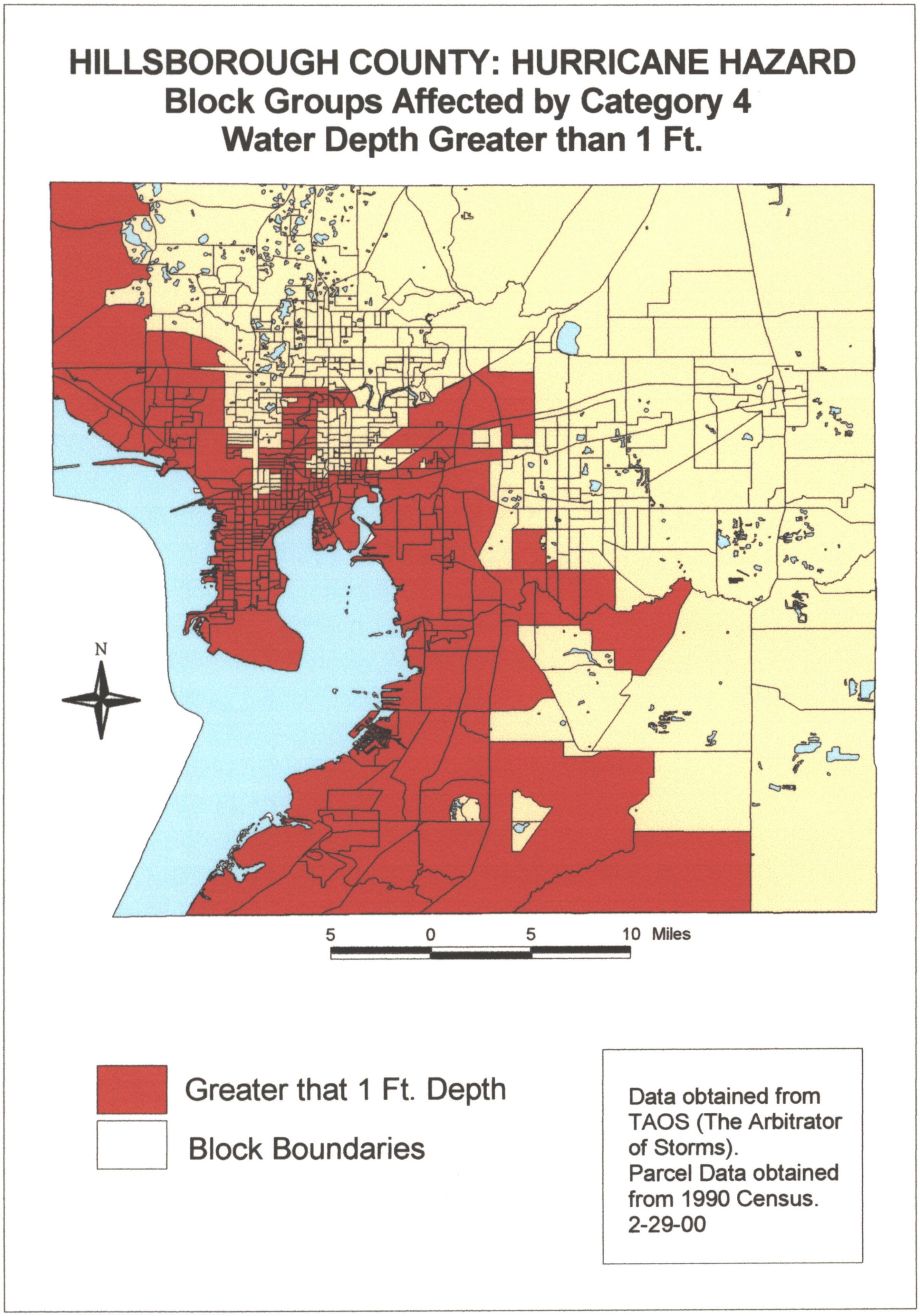

Fig. 42: Hillsborough County - Census blocks affected by hurricane category IV water depth greater than one foot.

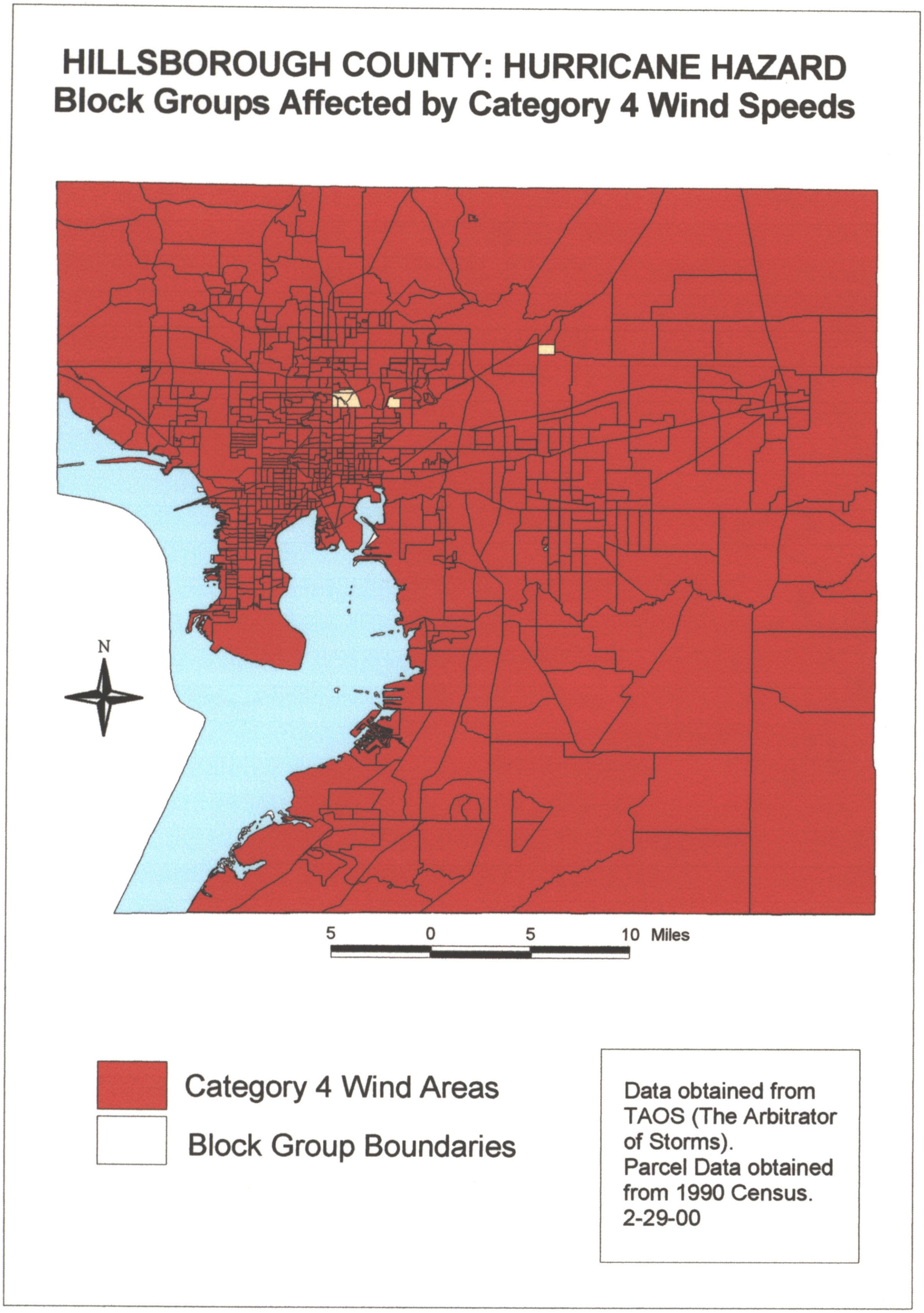

Fig. 43: Hillsborough County - Census blocks affected by hurricane category IV wind speeds.

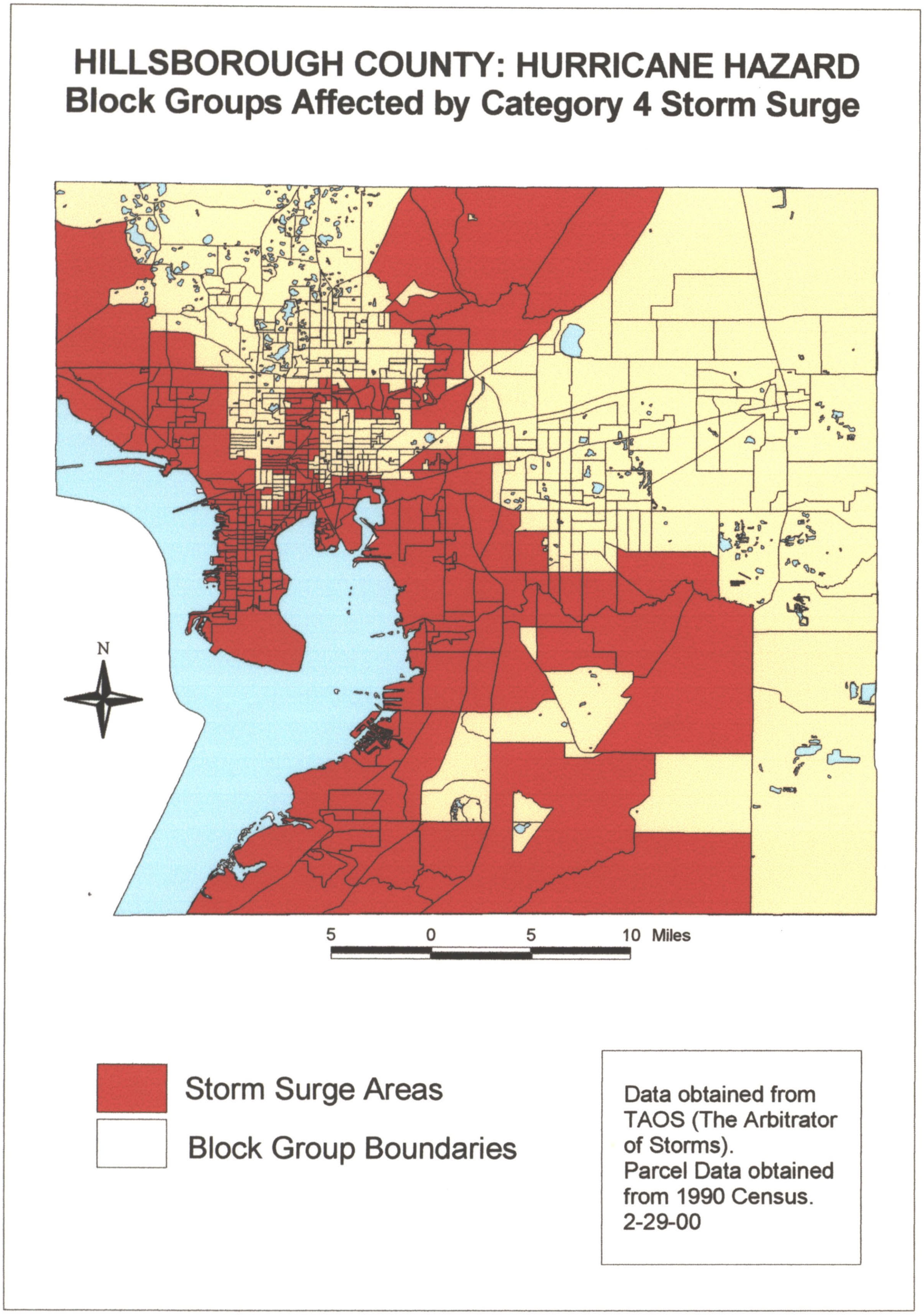

Fig. 44: Hillsborough County - Census blocks affected by hurricane category IV storm surge.

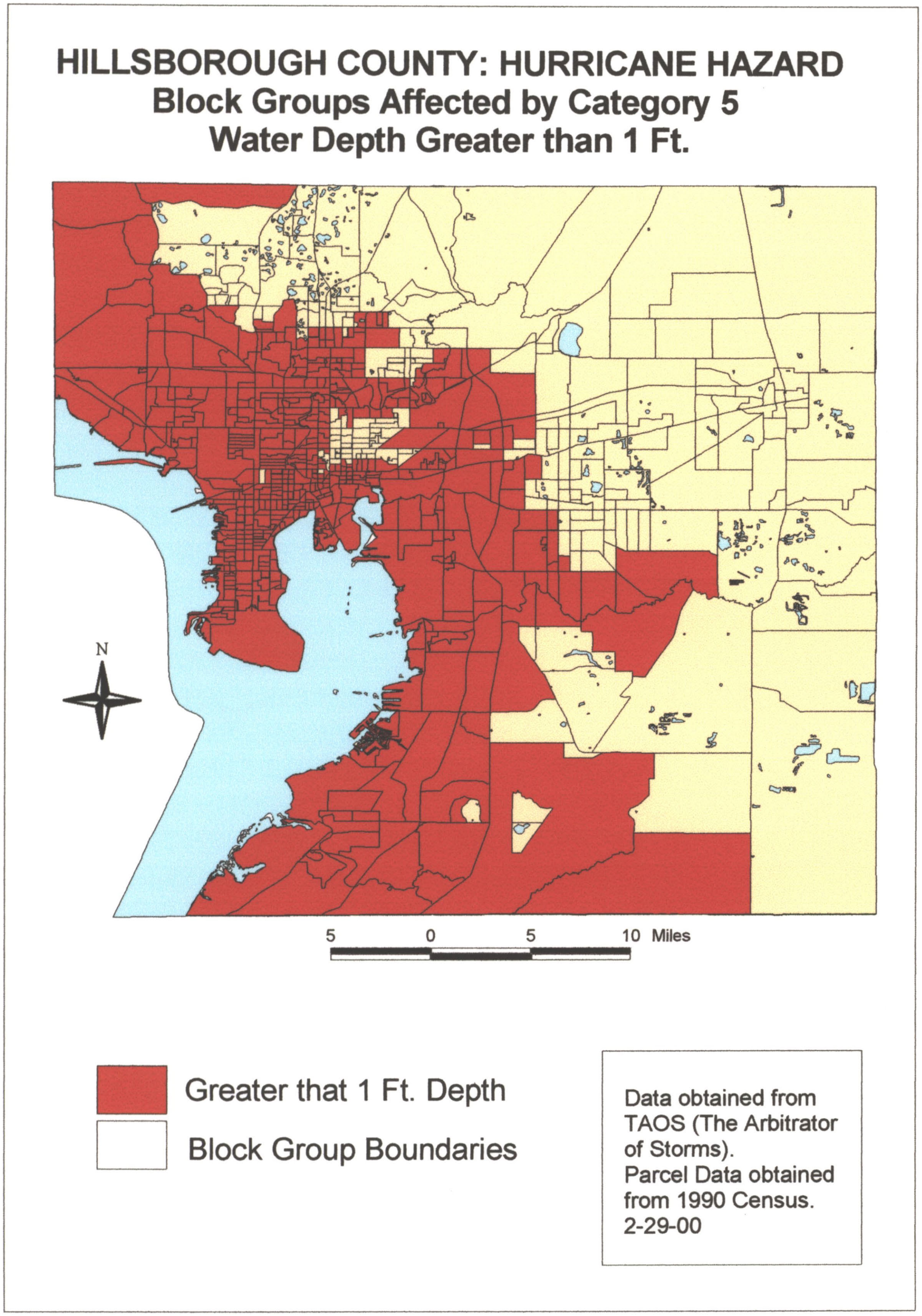

Fig. 45: Hillsborough County - Census blocks affected by hurricane category V water depth greater than one foot.

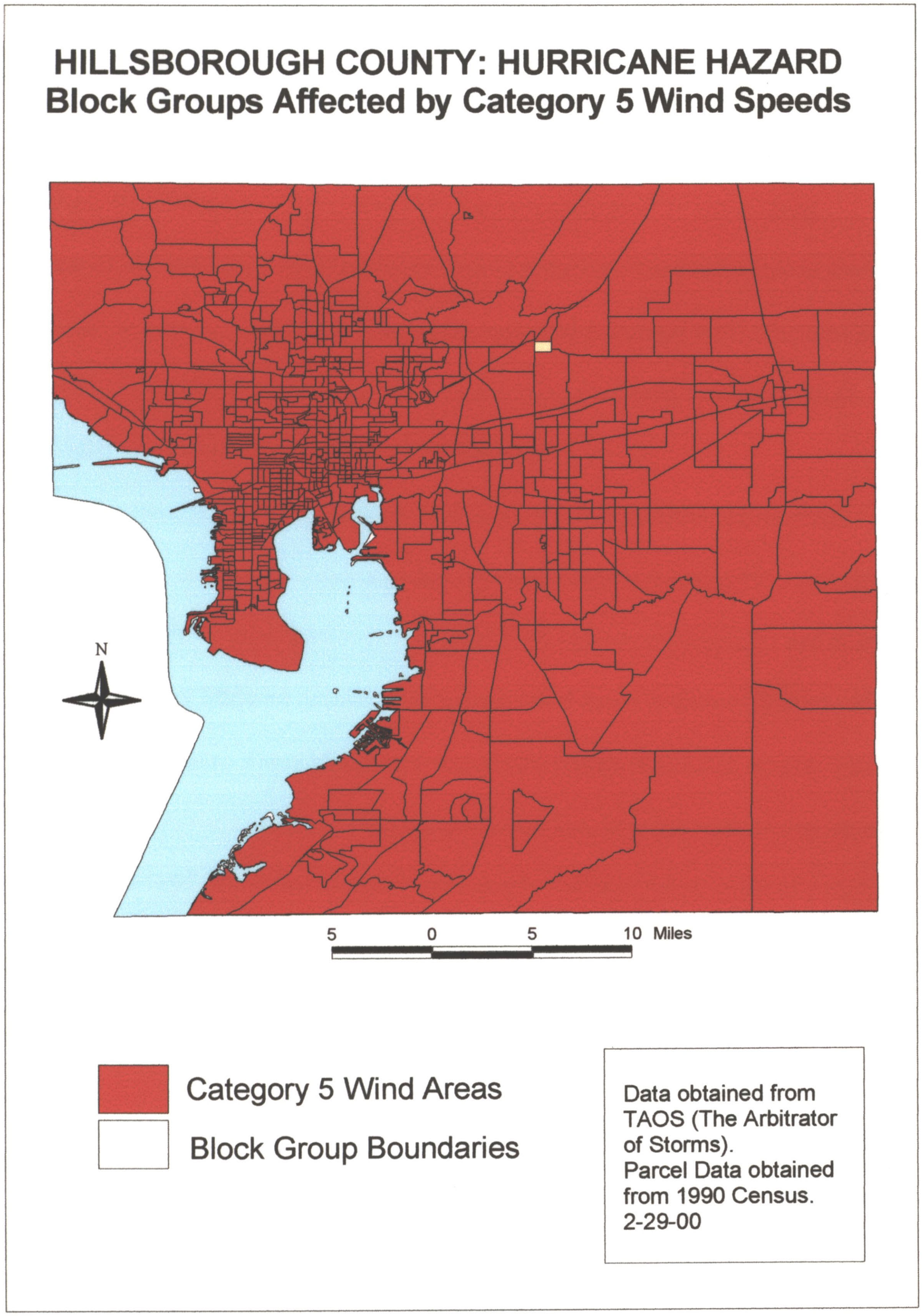

Fig. 46: Hillsborough County - Census blocks affected by hurricane category V wind speeds.

census blocks and could potentially engulf 581,161 people. Figure 47 displays the census blocks of Hillsborough County that would potentially be battered by hurricane category V storm surge. This wall of water would possibly inundate 408 census blocks and could endanger 409,554 people. This event will cause complete roof failure on many residences and industrial buildings, in addition to complete structure failures in some locations. A category V hurricane event will cause major damage to all structures located less than 15 feet above sea level. This event will necessitate total evacuation of all residential areas within 5 to 10 miles of the shoreline.

The tornado hazard is often not seen as a very large threat to Hillsborough County. On the contrary, Hillsborough has seen 90 tornadoes between 1950 and 1995, an average of two every year. Although tornadoes in Florida are often smaller and of less duration than their Midwest cousins, they have touched down in 64 census blocks in Hillsborough County. These blocks now include the homes of 113,925 people. Figure 48 depicts the census blocks of Hillsborough County that have been affected by tornadoes from 1950 to 1995. Note that tornadoes are hazards that have the potential of occurring anywhere in the county, rather than only in the areas shown in the graphic. These graphics serve as a valuable tool for identifying those areas that must be developed and utilized in a more sensitive fashion to allow for the potential for disaster to be abated.

Sinkholes are also a potential hazard threat that affects Hillsborough County. Although the whole county is not at risk of sinkholes ravaging homes and businesses, there are many areas in the county that are underlain by limestone that is being slowly dissolved. Figure 49 displays the census blocks of Hillsborough County that have been

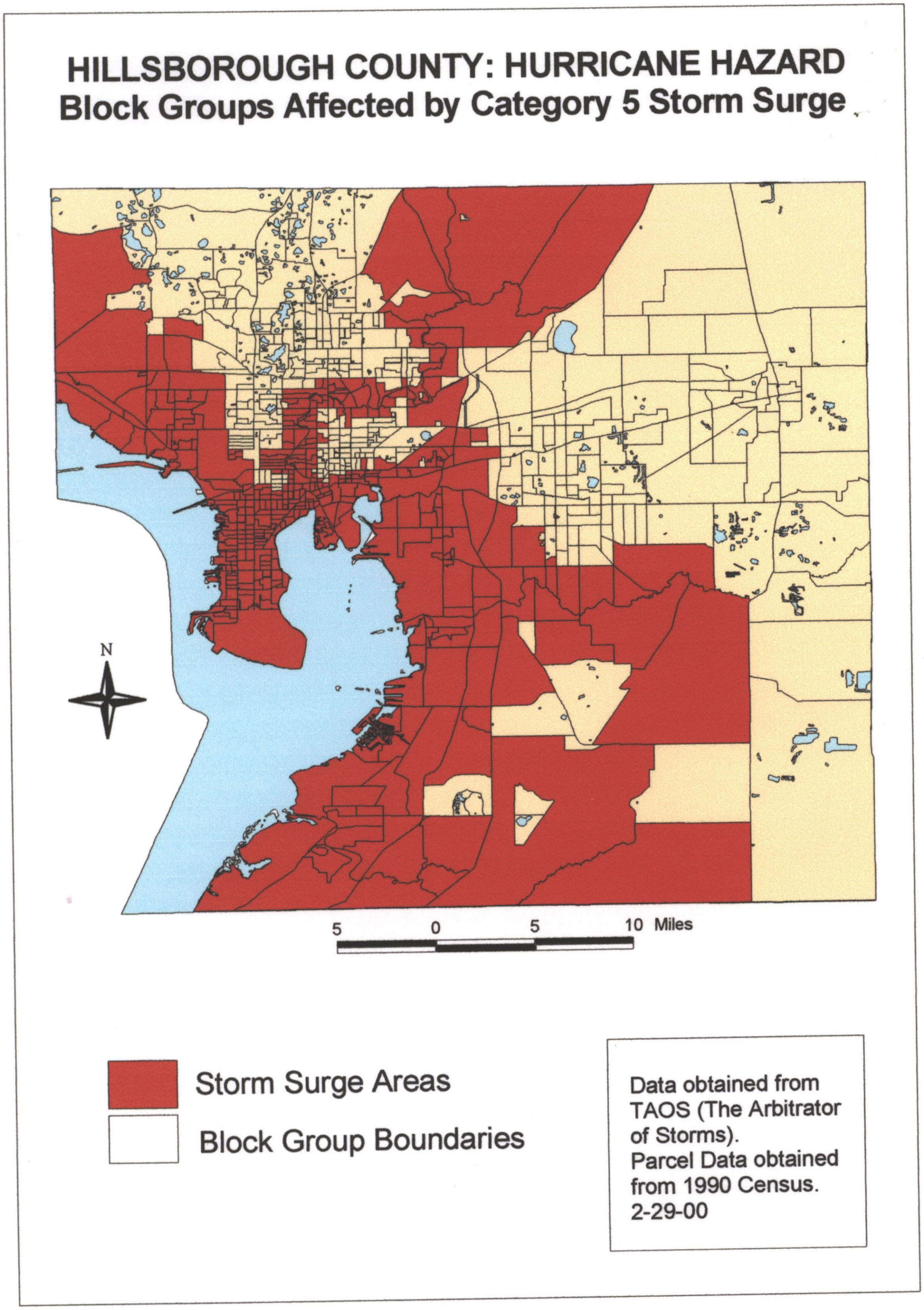

Fig. 47: Hillsborough County - Census blocks affected by hurricane category V storm surge.

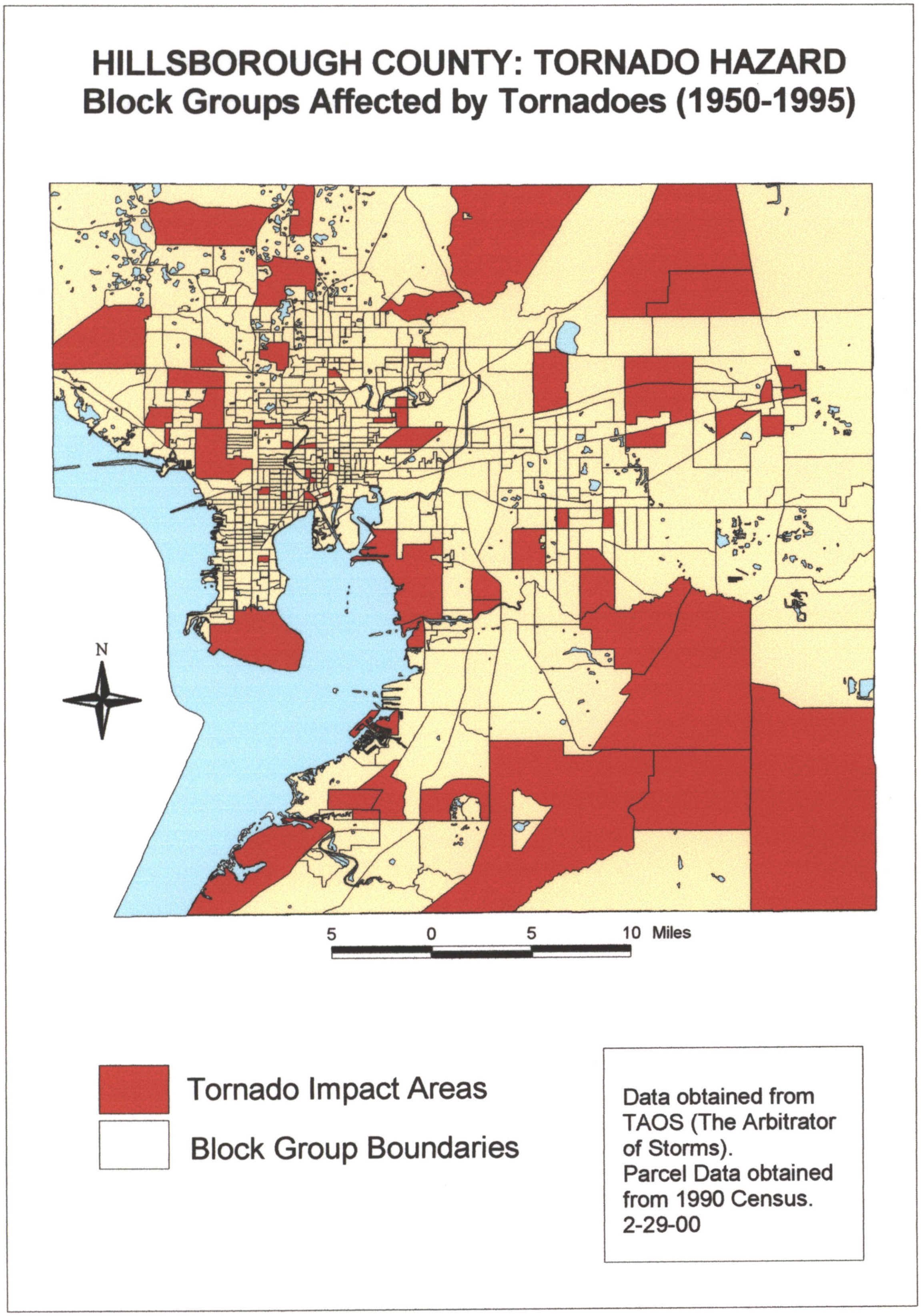

Fig. 48: Hillsborough County - Census blocks affects by tornadoes (1950 - 1995).

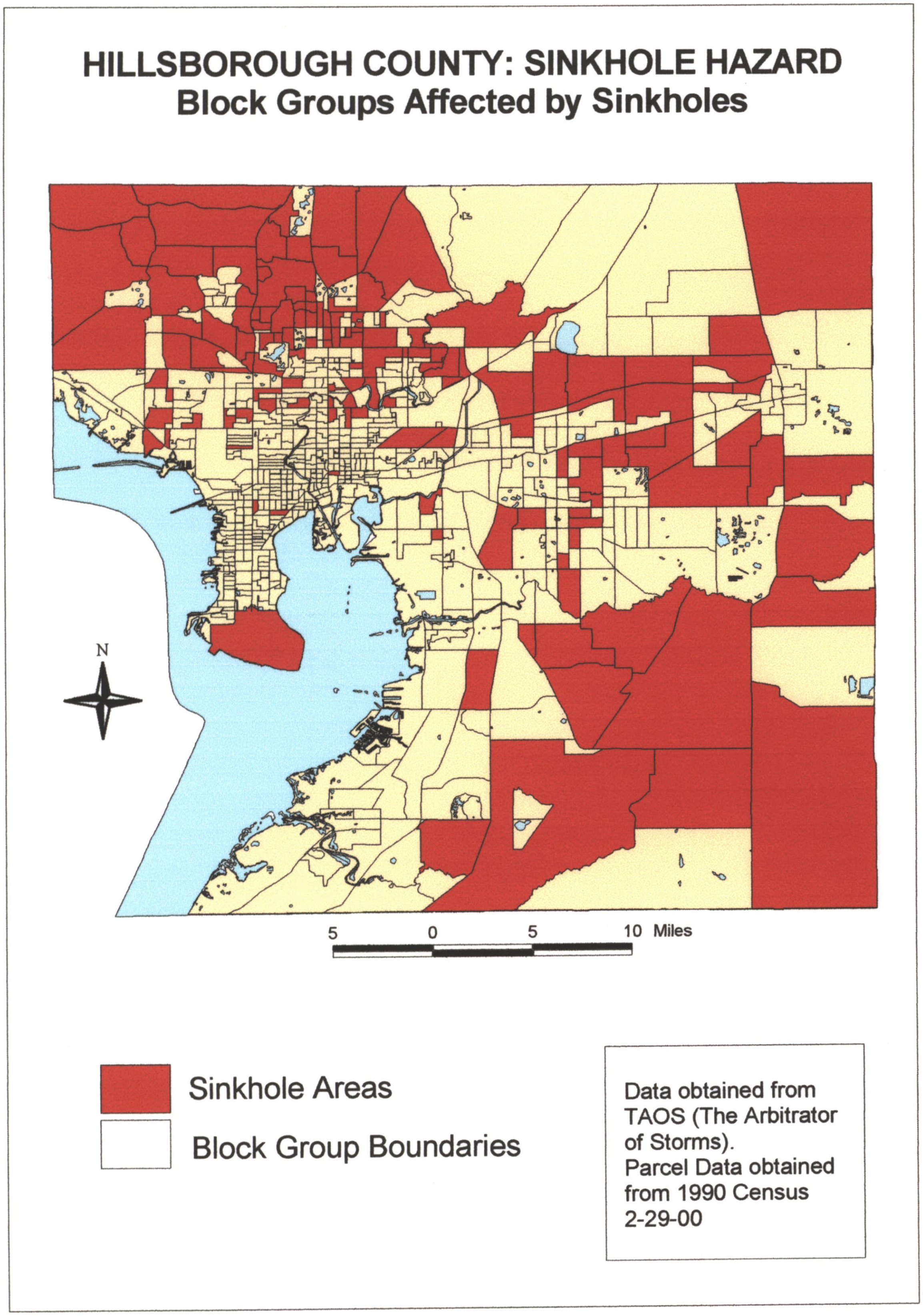

Fig. 49: Hillsborough County - Census blocks affected by sinkholes.

affected by sinkholes prior to 1995. These sinkholes have impacted 141 census blocks serving as homesteads for 248,288 people.

In addition to the above hazards that threaten Hillsborough County, there is also the hazard of riverine flooding. Flood events, although not as physically destructive as cyclones, have the potential to affect many square miles of land and hundreds of households. Figure 50 and Figure 51 show the census blocks of Hillsborough County that would be affected by the 100 and 500 year floods. The 100 year flood event would potentially inundate 494 census blocks and could disrupt the lives of 630,800 people, while the 500 year flood event would impact 520 census blocks and 652,804 people.

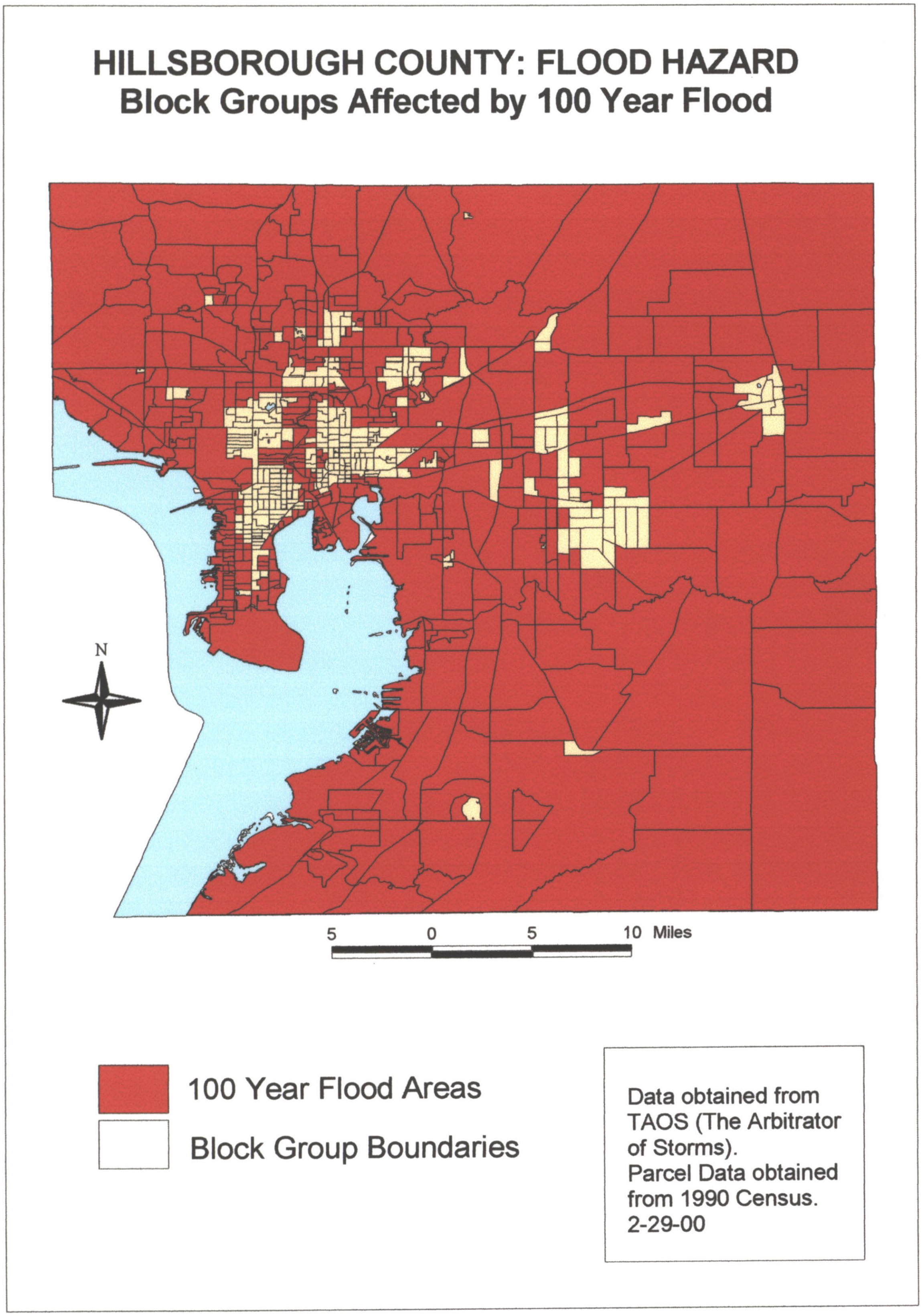

Fig. 50: Hillsborough County - Census blocks affected by the 100-year flood event.

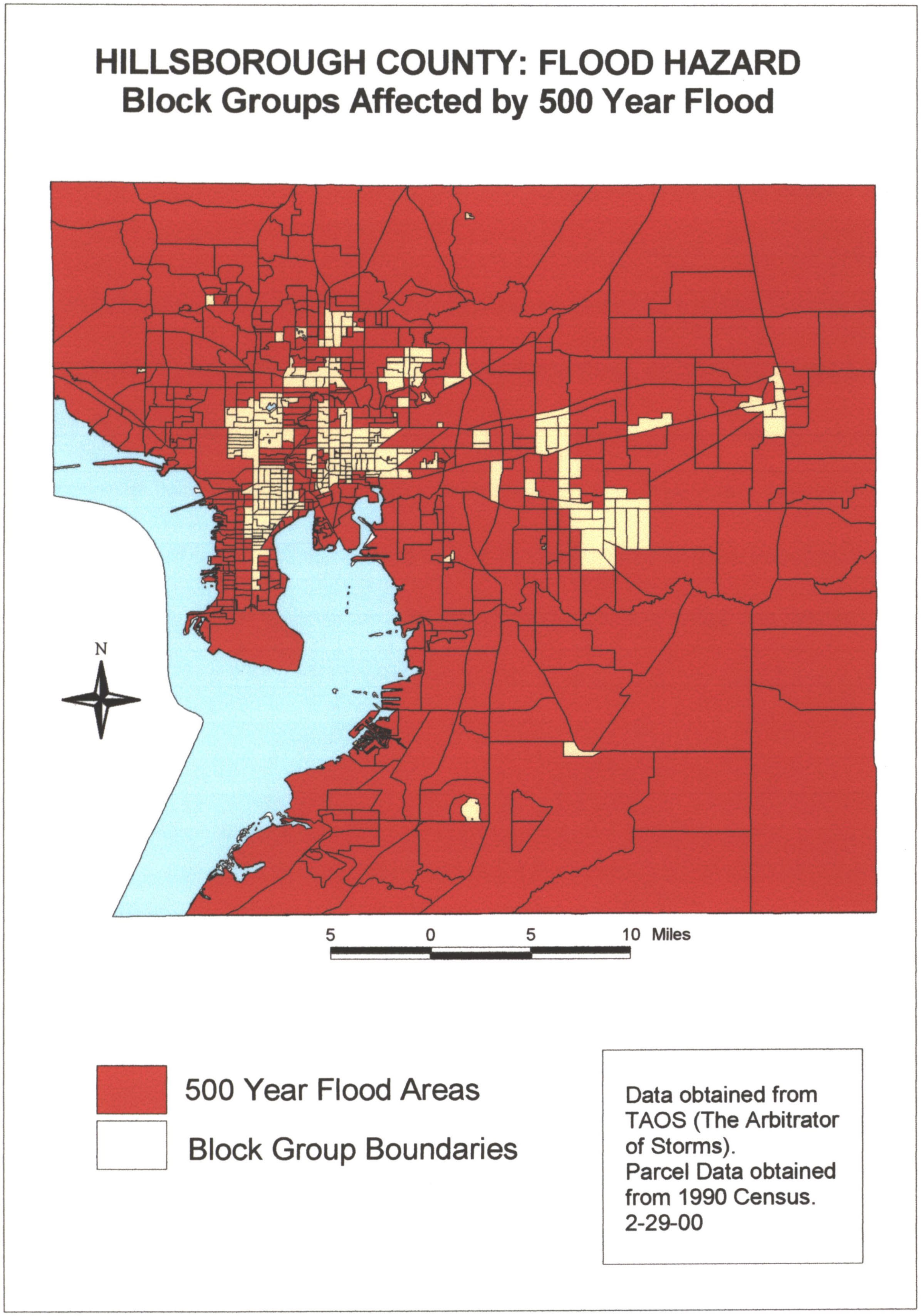

Fig. 51: Hillsborough County - Census blocks affected by the 500-year flood event.

Multiple Hazard Risk Assessment

The data show many census blocks that are potentially at risk to multiple hazards. These areas, in particular, must be zoned and developed, or in some cases, rezoned and/or left undeveloped in order to accommodate the potential for disasters. Figure 52 depicts the census blocks of Hillsborough County that are risk to multiple natural hazards. These hazards include sinkholes, tornadoes, 100 and 500 year flood, and hurricane category V storm surge, wind speed, and wave height. Note that the above stated hazards are not the only potential hazards for Hillsborough County. These hazards provide a baseline for the worse case scenario, or the highest amount of area that could potentially be affected by multiple hazards. Table 4 shows the total square miles, the population that has the potential to be affected by each number of multiple hazards, and the areas that would be impacted.

Community Vulnerability Factors

As discussed earlier, there are social factors that either make a person or community more vulnerable or less vulnerable to the effects of a hazard. For the purpose of this research, the following social characteristics were chosen to define community vulnerability: population density, housing density, housing status, housing type, house value, number of females, number of persons under age 18, and number of persons over age 65. These factors were analyzed and the vulnerability scores between 0 and 1 were defined for each.

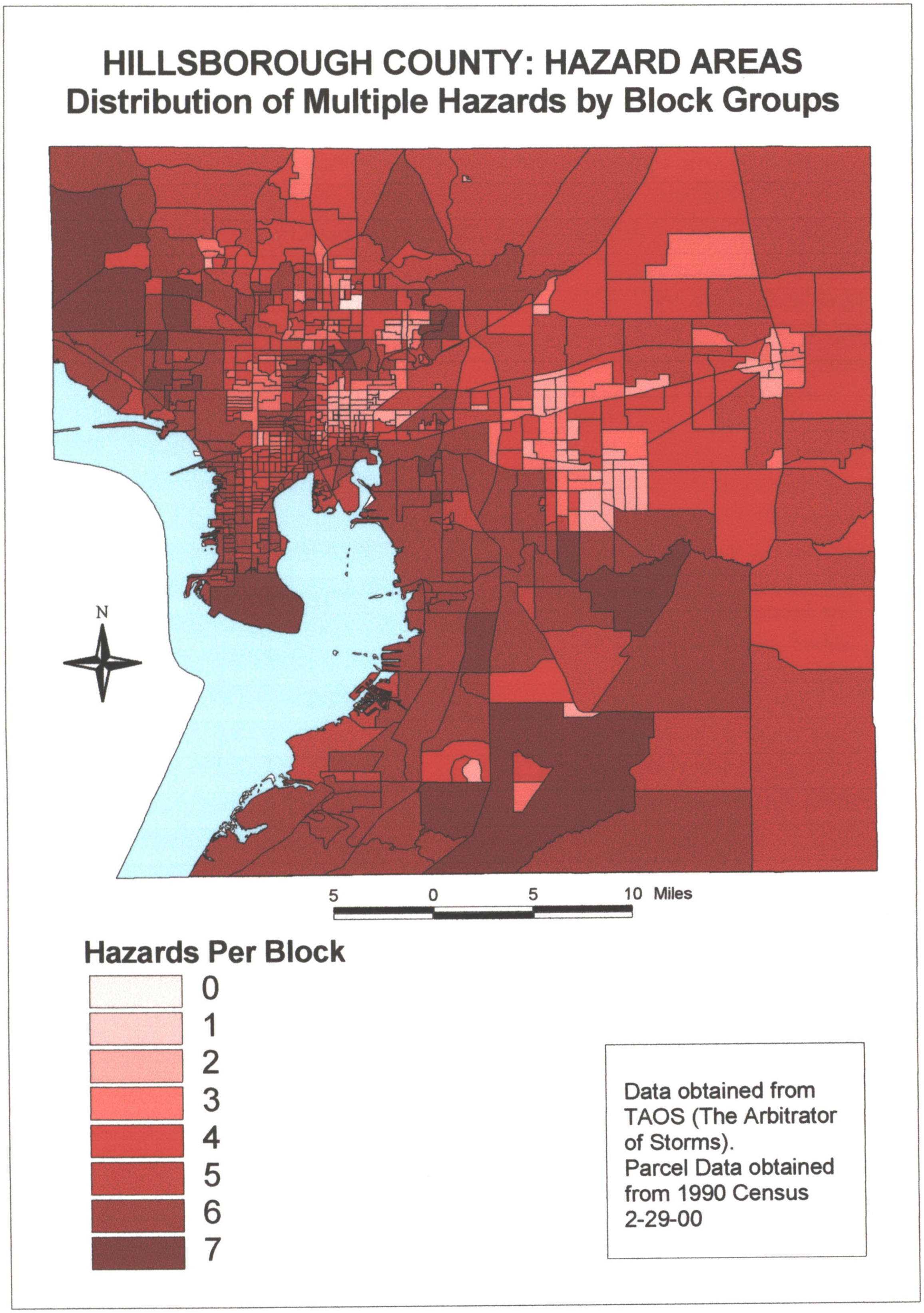

Fig. 52: Hillsborough County - Census blocks affects by multiple hazards.

Table 4. Hillsborough County - Multiple Hazards: Number of census blocks, population, total square miles and locations of blocks affected by each number of multiple hazards.

# of Hazards per block	# of Blocks Affected	Population Affected	Total Area Affected	Location of Blocks
0	1	3,511	0.65	15th Street - 30th Street Fowler Avenue - N. 27th Street Fowler Avenue - E. 127th Ave
2	88	83,013	28.64	Carrollwood, Old Carrollwood, Central and Southern Hillsborough, Temple Terrace
3	112	107,121	50.94	North Hillsborough, West and West Central Hillsborough, South Tampa, North Tampa
4	189	193,704	220.43	Northeast, Central and Eastern Hillsborough
5	132	146,760	336.76	Southeast, North central and North Hillsborough, South Tampa, Davis and Harbor Island
6	237	280,559	366.54	Coastal and Central Hillsborough and Central Tampa
7	24	50,734	115.83	South central, Central, and Northwest Hillsborough, McDill AFB

The population density vulnerability score for each census block group in Hillsborough County is shown in Figure 53. The highest population density scores were found in 16 census blocks in the areas of northwest, south central, east central, and central Hillsborough County, as well as the area surrounding the University of South Florida. Of these 16 census blocks, 3 have a score greater than 0.9. These areas of higher population correlate to areas of increased new development, as is the case in the New Tampa and Town and Country areas. In addition, higher population scores were found in areas that act as small communities surrounded by relatively undeveloped land within the

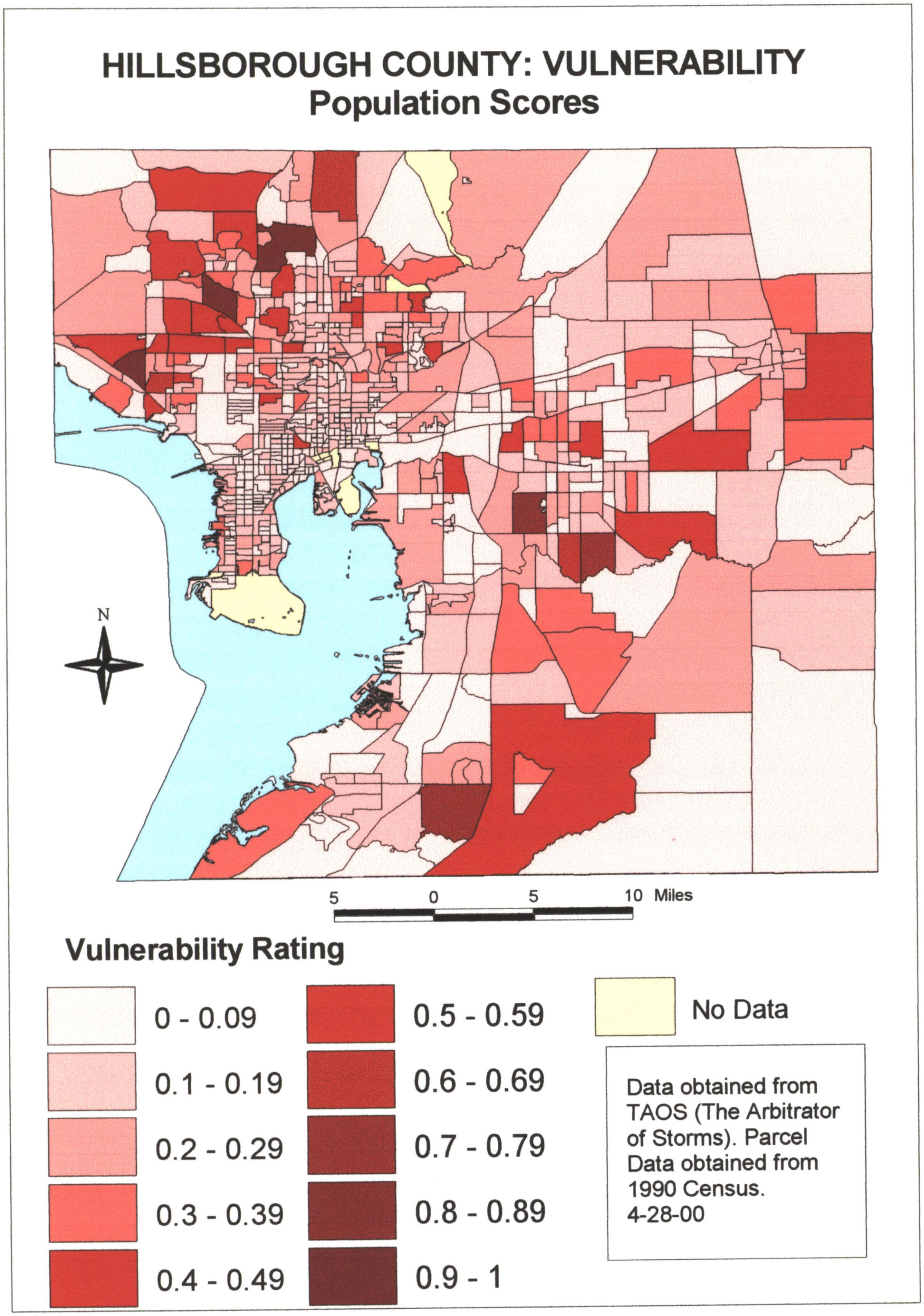

Fig. 53: Hillsborough County - Population density vulnerability scores by block group.

county. These areas include Brandon and other smaller towns throughout central Hillsborough.

The housing density vulnerability score for each census block group in Hillsborough County is shown in Figure 54. The highest housing density scores were found in 17 census blocks in the areas of Carrollwood, Lutz, south central, west central and central Hillsborough County. four of these blocks have a score in excess of 0.9. The higher housing density scores roughly match the areas that were found to have higher populations. Increased development in these areas, primarily subdivisions, pack houses more closely thus leading to higher housing density scores.

The housing status, or the renter occupied housing vulnerability score for each census block group in Hillsborough County is shown in Figure 55. The highest housing status scores were found in 28 census blocks, two of which had scores greater than 0.9. These census blocks are scattered throughout Hillsborough County, most in central and north Tampa and in the area of USF. The renter occupied housing scores correspond mainly to areas around the University of South Florida as well as north Tampa, where affordable apartments and condominiums are being built to compensate for the ever increasing population that is moving into the area.

The housing type, or the mobile home vulnerability score for each census block group in Hillsborough County is shown in Figure 56. The highest housing type scores were found in ten census blocks in the areas of south central, central, northeast and southwest Hillsborough County. Three of these blocks were found to have the scores in excess of 0.9. Higher mobile home scores are found predominantly in the areas of the county that are more rural. Many of these areas correspond to portions of the county that

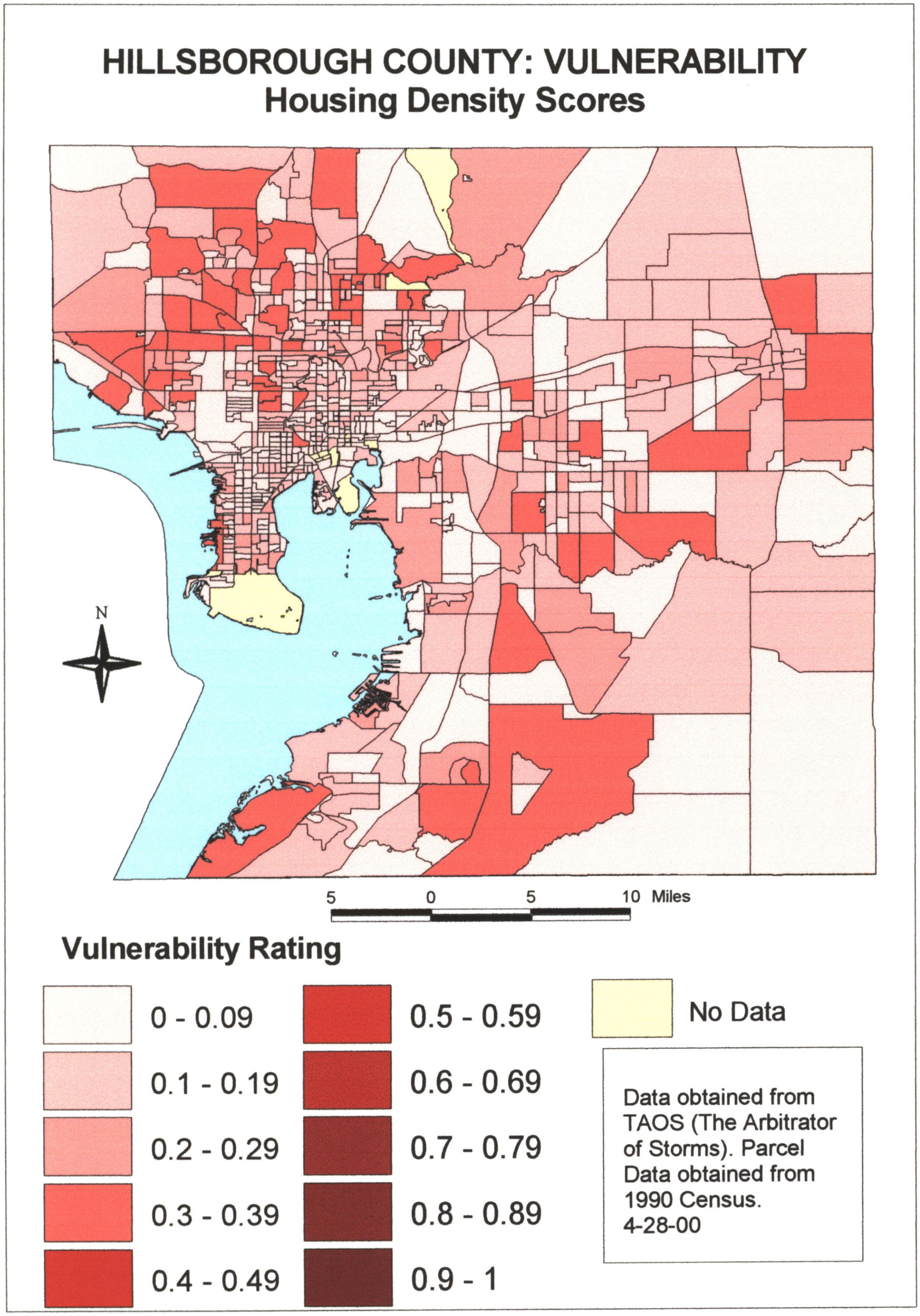

Fig. 54: Hillsborough County - Housing density vulnerability scores by block group.

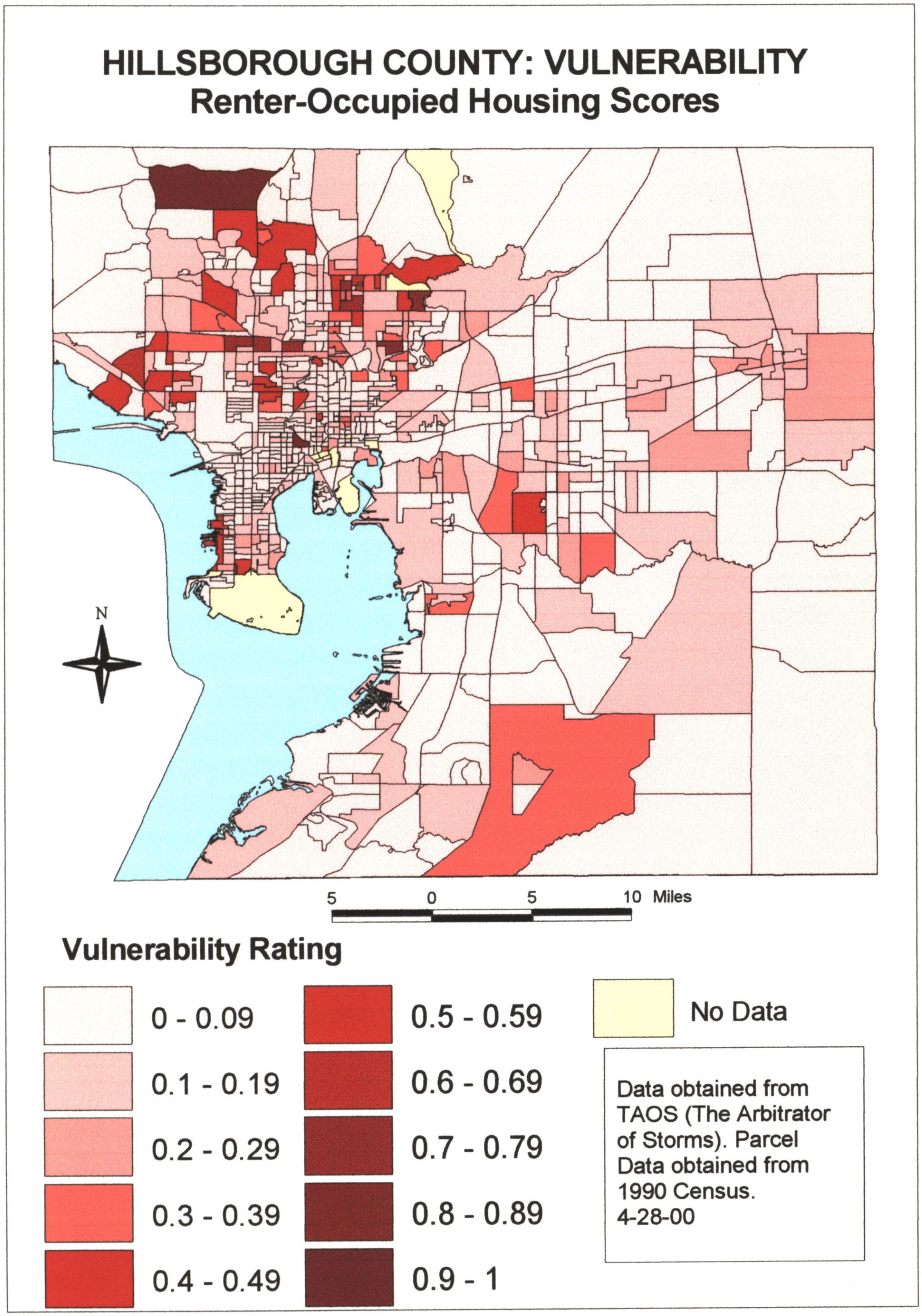

Fig. 55: Hillsborough County - Renter-Occupied housing vulnerability scores by block group.

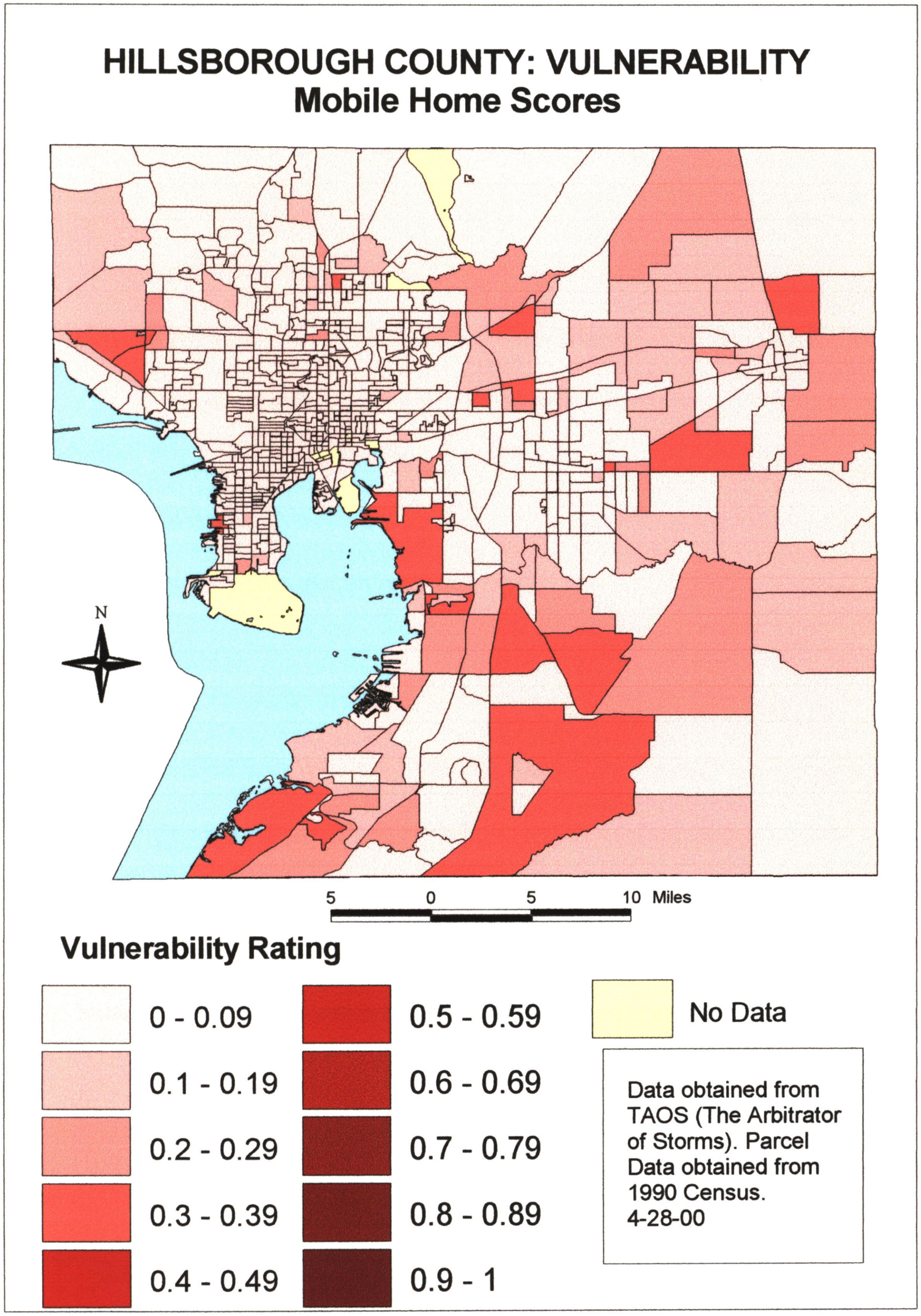

Fig. 56: Hillsborough County - Mobile home density vulnerability scores by block group.

are used for agricultural purposes. In addition, higher scores are found along the coastal areas of the county. These higher populations of mobile homes correspond to areas of the county that are normally used as retirement and vacation destinations.

The mean house value vulnerability score for each census block group in Hillsborough County is shown in Figure 57. The highest house value scores were found in 332 census blocks. Only one of these blocks was found to have a score greater than 0.9. Most of these blocks are located in the areas outside incorporated Tampa and the coastal areas. Some of these blocks were found in the Carrollwood and Town and Country areas, as well as east central and south central Hillsborough County and extreme south Tampa to the north of McDill Air Force Base.

The female vulnerability score for each census block group in Hillsborough County is shown in Figure 58. The highest female scores were found in 20 census blocks in the areas of south central, central, eastern and north western Hillsborough County. Only two of these census blocks were found to have a score greater than 0.9. The presence of higher female populations also corresponds to new development in Hillsborough County. In particular, the Town and Country area was found to be an area of high female populations, in addition to the Brandon, Ruskin and Sun City Center areas.

The dependent population under age 18 vulnerability score for each census block group in Hillsborough County is shown in Figure 59. The highest under age 18 scores were found in 18 census blocks in the areas of Lutz, northwest, south, south central and central Hillsborough County. Three of these blocks were found to have scores greater than 0.9. Higher amounts of young dependents also correspond to the areas of new

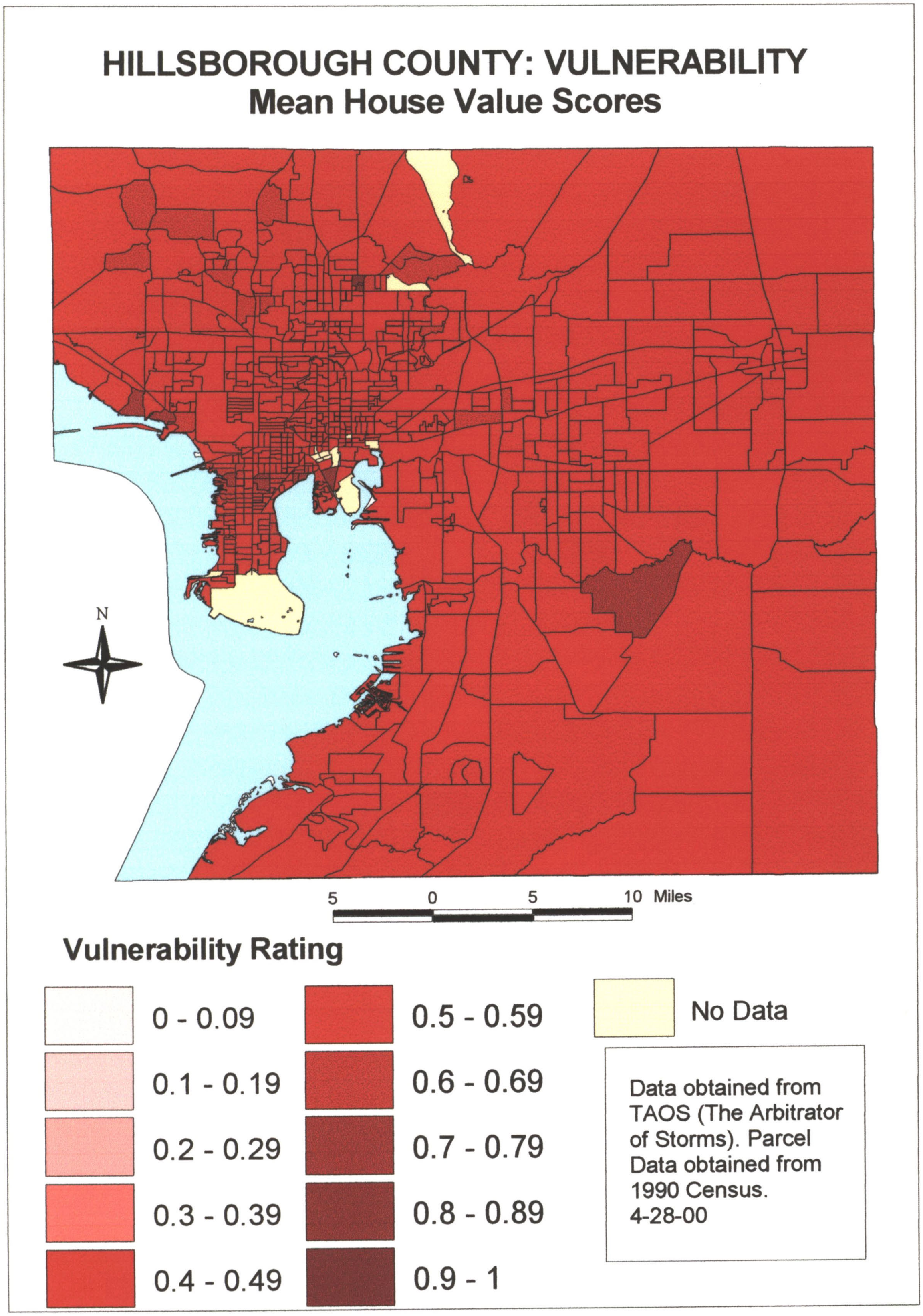

Fig. 57: Hillsborough County - Median house value vulnerability scores by block group.

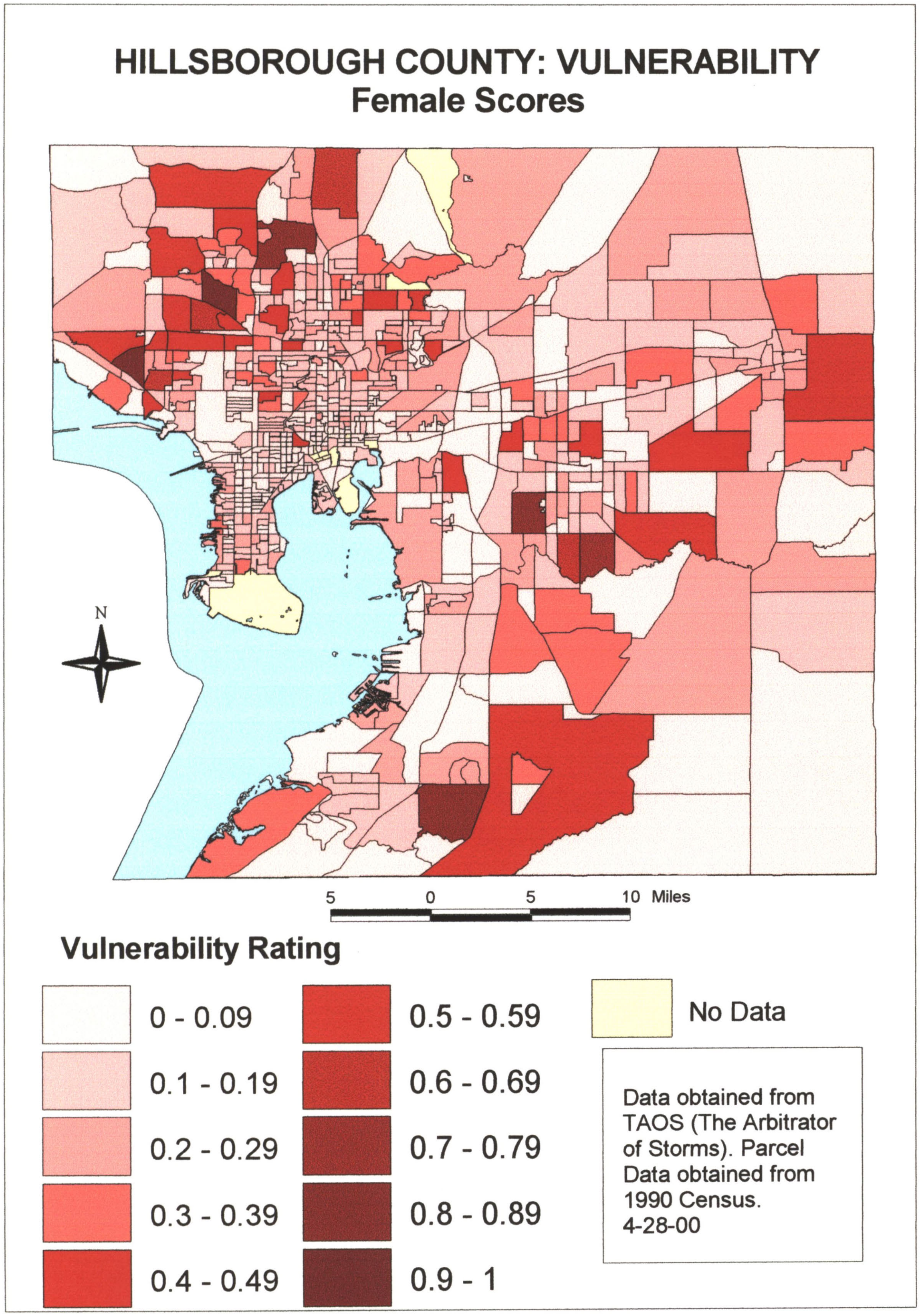

Fig. 58: Hillsborough County - Female vulnerability scores by block group.

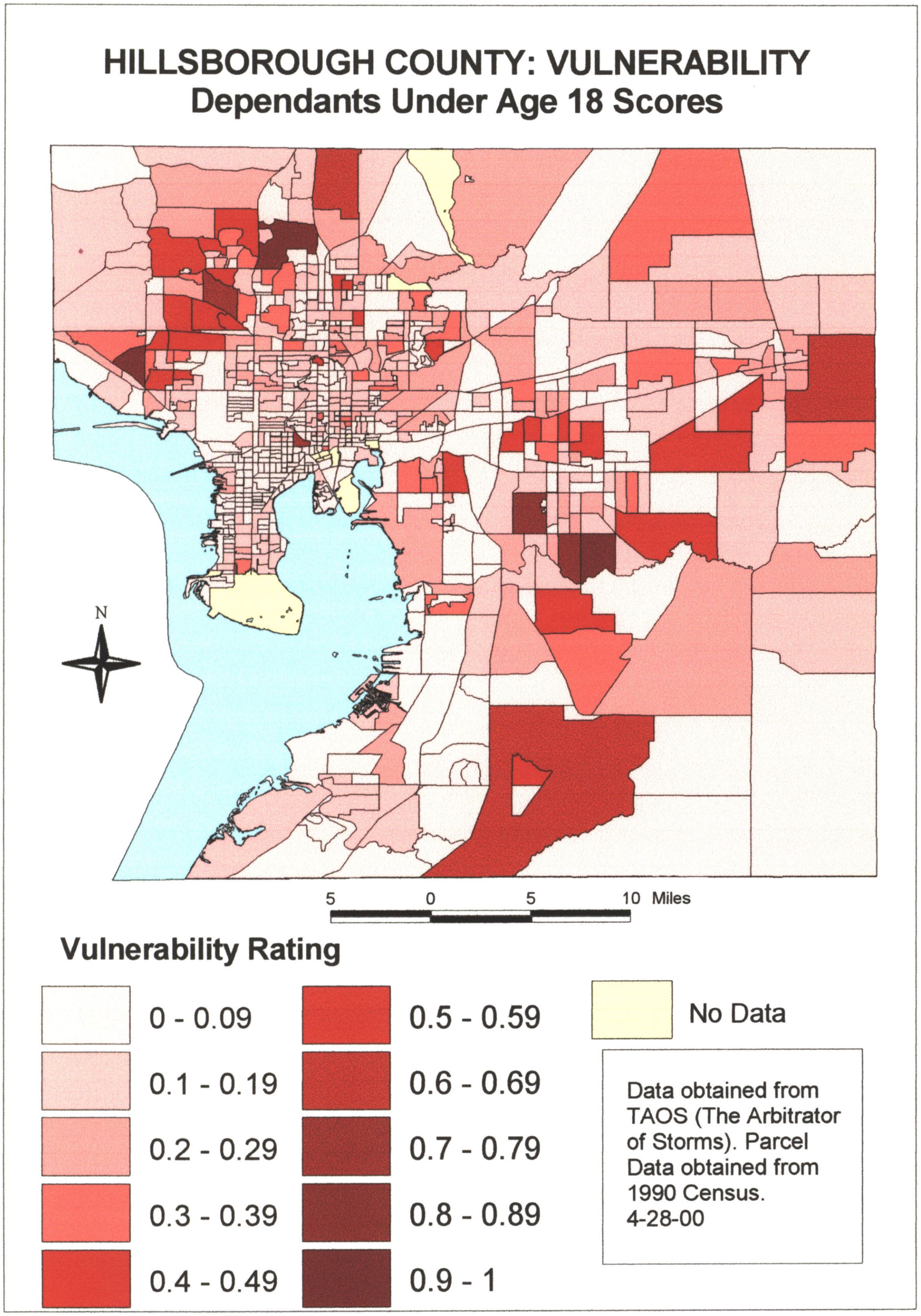

Fig. 59: Hillsborough County - Dependents under age 18 vulnerability scores by block group.

development. This new development is aimed at family units rather than single apartments, thus providing a good place for new families to reside.

The dependent population over age 65 vulnerability score for each census block group in Hillsborough County is shown in Figure 60. The highest over age 65 score was found in 1 census block located in southern Hillsborough. This block was found to have 940 persons over the age of 65 or less than 1% of this dependent population. Retirement areas and older residential areas throughout the county are found to have the highest dependent populations over age 65. These areas include part of the county that have been in existence for many years, as well as portions of the county know to be retirement communities, including Sun City Center and older parts of the city.

The non-white population vulnerability score for each census block group in Hillsborough County is shown in Figure 61. The highest non-white scores were found in 8 census blocks in the areas of west and south central Hillsborough County and scattered throughout central Tampa. One of these blocks were found to have scores greater than 0.9. A majority of the high non-white vulnerability scores were found with the city limits of Tampa, as well as in the older residential areas of the county. In addition, high non-white scores were found in the more rural portions of the county.

Overall Community Vulnerability

The researcher's goal was to determine the social vulnerability of Hillsborough county to multiple natural hazards. To this extent, the results are as follows:

Based on the equation for social vulnerability developed for this research, in which social factors of vulnerability are summed to obtain an overall vulnerability score,

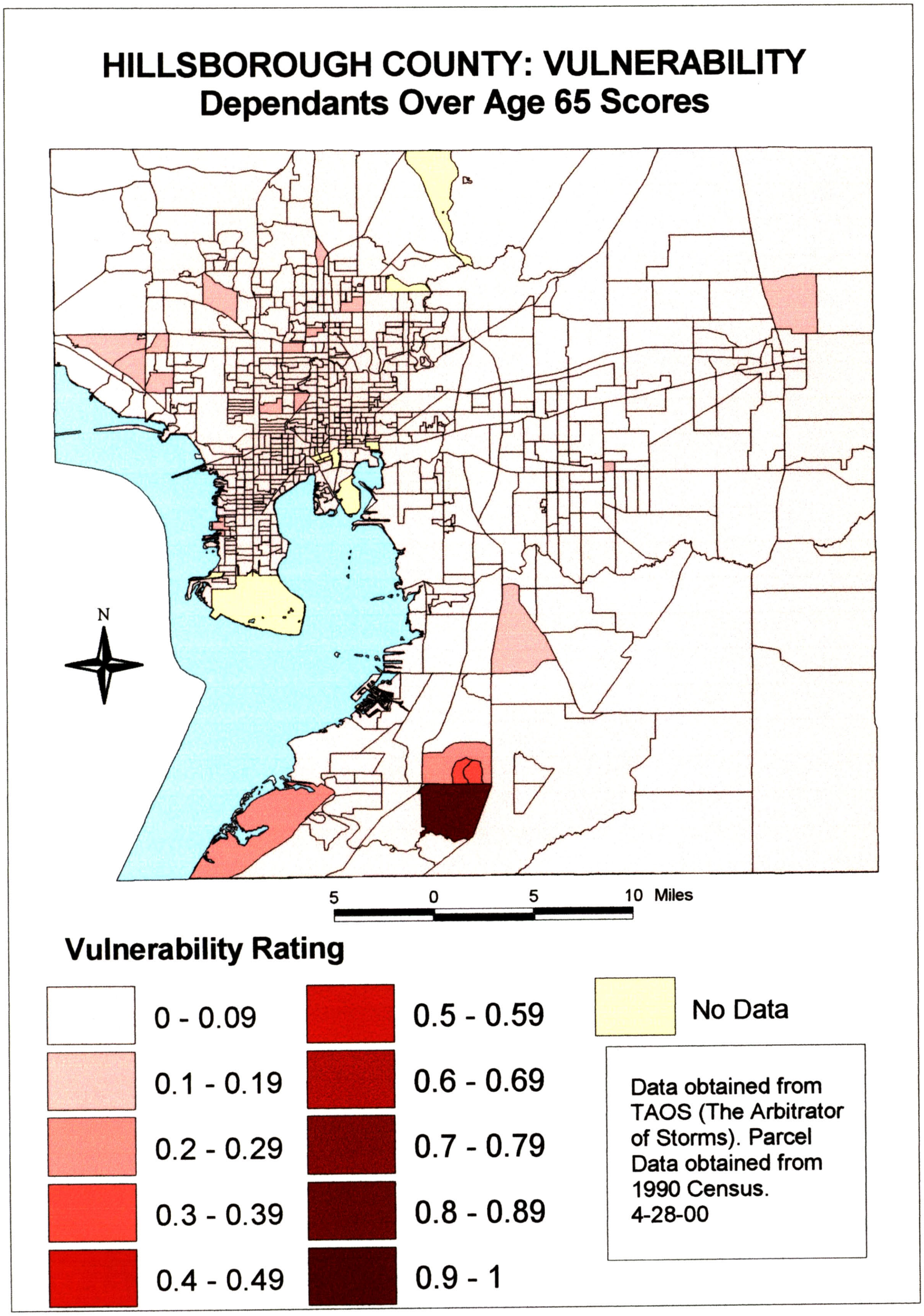

Fig. 60: Hillsborough County - Dependents over age 65 vulnerability scores by block group.

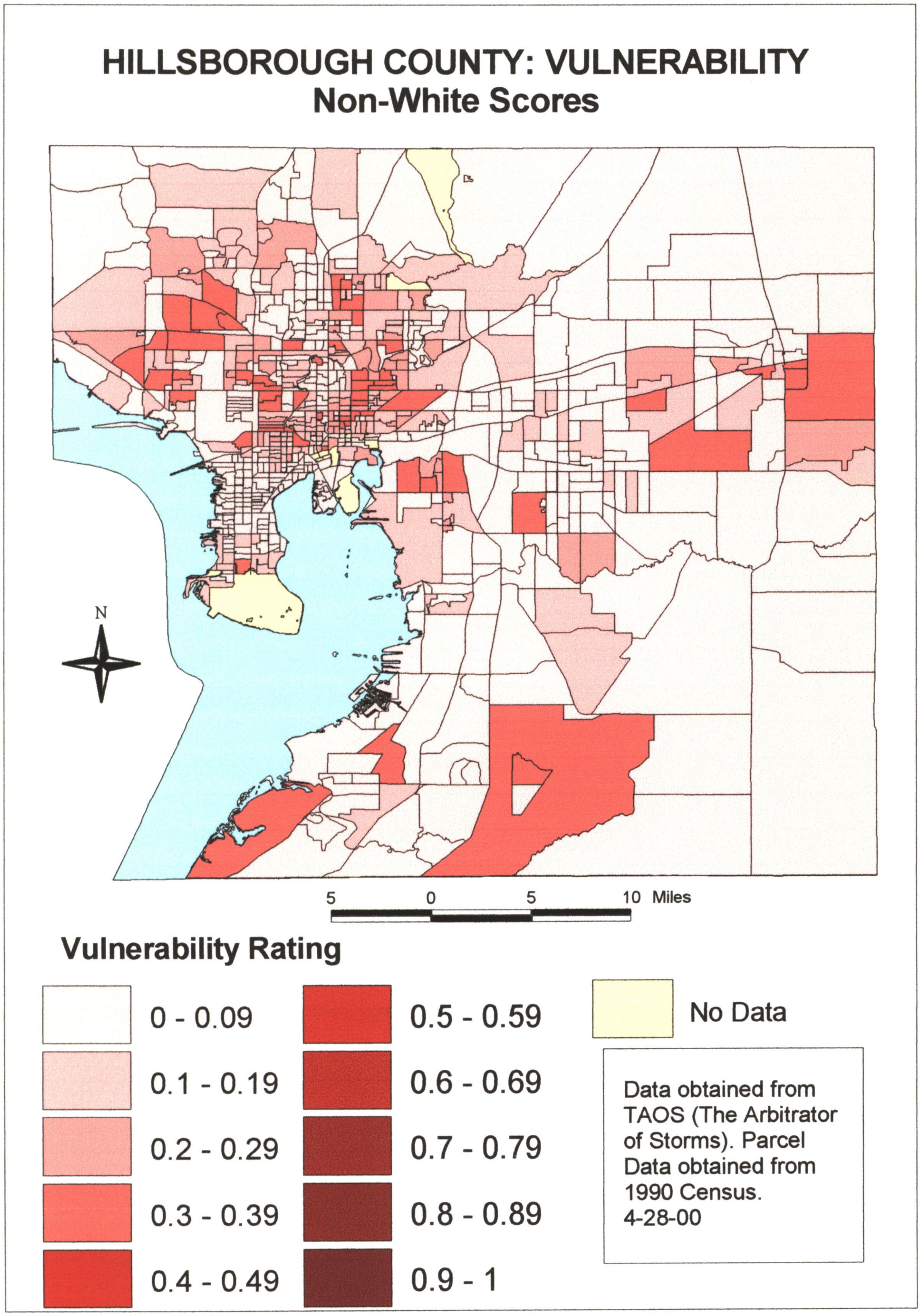

Fig. 61: Hillsborough County - Non-white vulnerability scores by block group.

the census blocks of Hillsborough County were analyzed. The equation for vulnerability developed for this research is thus theoretically stated:

$$V = f(X1 + X2 + X3 \ldots\ldots Xn)$$

where V is equal to community vulnerability and X1 through Xn represent social factors that contribute to vulnerability. The final equation of community vulnerability, as it corresponds to this research is:

$$CV = f(PS + HDS + ROHS + MHS + HVS + FS + {<}18S + {>}65S)$$

where CV is the overall community vulnerability as a function of the sum of the social characteristics of vulnerability;

PS = Population Score

HDS = Housing Density Score

ROHS = Renter- Occupied Housing Score

MHS = Mobile Home Score

HVS = Mean House Value Score

<18S = Dependents Under Age 18 Score

>65S = Dependents Over Age 65 Score

Figure 62 delineates the census blocks of Hillsborough County by their overall community vulnerability scores based on the researcher's equation of vulnerability. The county was found to have one major area of high vulnerability. This area of increased vulnerability is located in the northwestern portion of the county and includes 7 census blocks comprised of 17,490 households. Other locations in the county that have the highest vulnerability scores are south central and east central Hillsborough as well as the area surrounding the University of South Florida. Overall, the county was found to

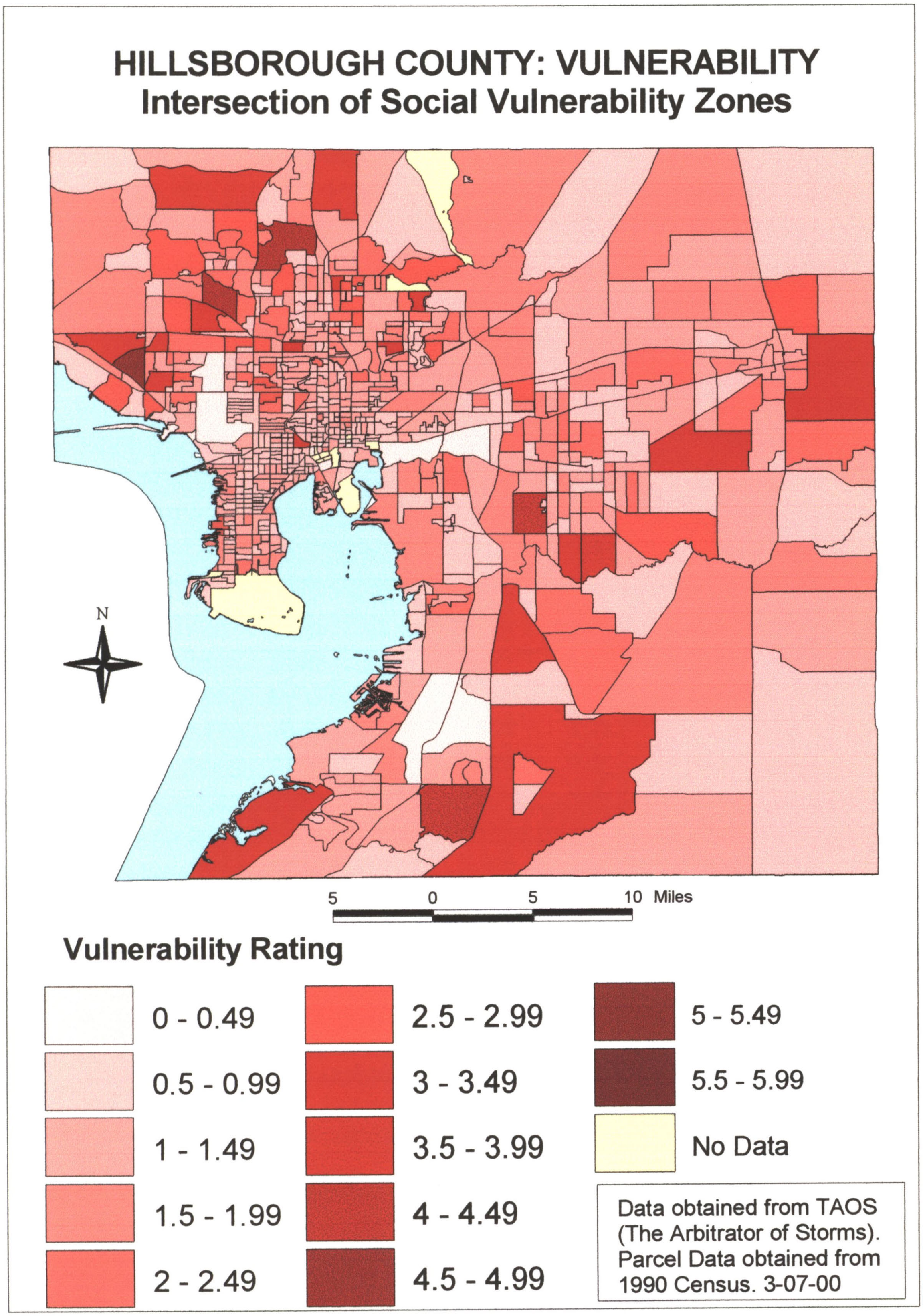

Fig. 62: Hillsborough County - Community vulnerability scores based on vulnerability equation #1.

exhibit vulnerability scores that were heavier on the low end of the scale. Table 5 shows the Percentage of each vulnerability characteristic occurring by vulnerability score. In addition, Table 6 shows the number of census blocks encompassed by each vulnerability score, as well as the area and number of households in each level of score.

Table 5: Hillsborough County - Percentage of each vulnerability characteristic occurring by vulnerability score

Score	Area (square miles)	Population Density (persons per sq. mile)	Housing Units	Mobile Homes	Age Under 18	Age Over 65	Female Density	Renter Occupancy
0 - 0.49	2.73	0.0016	0.0014	0.0011	0.0005	0.0009	0.0006	0.0008
0.5 - 0.99	31.04	20.08	19.96	12.98	18.92	23.68	19.81	18.06
1 - 1.49	25.9	32.27	31.45	32.62	33.41	33.54	32.79	30.2
1.5 - 1.99	17.68	18.15	17.38	16.49	19.08	16.64	18.14	15.56
2 - 2.49	4.27	8.26	8.04	7.98	8.23	4.79	8.16	10.65
2.5 - 2.99	5.92	10.08	10.9	14.08	9.82	7.66	9.94	12.51
3 - 3.49	9.94	6.64	7.32	13.23	6.59	7.37	6.6	8.9
3.5 - 3.99	0.0088	0.0041	0.0056	0.0004	0.0023	0.0037	0.0045	0.001
4 - 4.49	1.3	2.27	2.44	0.002	1.88	4.92	2.29	1.36
4.5 - 4.99	0.0019	0.0083	0.0088	0.0049	0.0078	0.0044	0.0087	0.0067
5 - 5.49	0.0015	0.009	0.0093	1.77	1	0.0049	0.0089	0.008
5.5 - 5.99	0	0	0	0	0	0	0	0

These data where then analyzed using Cutter's equation of vulnerability. This equation of vulnerability is theoretically shown here:

$$V = f(X1 + X2 + X3 \ldots\ldots + Xn)$$

where V is overall vulnerability and X1 through Xn are social characteristics of vulnerability.

Table 6: Hillsborough County - Number of blocks, area, and households affected by vulnerability score

Score	Area (square miles)	# of Census Blocks	# of Households
0 - 0.49	30.05	16	259
0.5 - 0.99	307.07	339	64,443
1.0 - 1.49	281.46	230	99,396
1.5 - 1.99	219.68	91	63,825
2.0 - 2.49	60.29	36	35,061
2.5 - 2.99	38.52	23	31,469
3.0 - 3.49	142.71	18	26,823
3.5 - 3.99	3.46	2	3,140
4.0 - 4.49	10.02	2	5,810
4.5 - 4.99	6.44	2	5,566
5.0 - 5.49	-	-	-
5.5 - 5.99	1.66	1	2,974

Cutters overall vulnerability equation as it corresponds to her research in South Carolina is:

$$V = f\,(PS + HDS + MHS + HVS + FS + DS + NWS)$$

where V is the overall community vulnerability as a function of the sum of the social characteristics of vulnerability;

PS = Population Score

HDS = Housing Density Score

MHS = Mobile Home Score

HVS = Mean House Value Score

DS = Dependent Score

NWS = Non-White Score

Figure 63 delineates the census blocks of Hillsborough County by their overall community vulnerability scores based on the Cutter model of vulnerability. Using this equation, the county was found to have 3 areas of high vulnerability. These areas of greater vulnerability are located in the same locations as the areas delineated by vulnerability equation #1, with the addition of one block located in the south central part of the county and included 8 census blocks comprised of 1032 households. This model also depicted a Hillsborough County with relatively low vulnerability scores.

Hillsborough county was found to have a wide range of vulnerability scores based on the researcher's equation for community vulnerability. Table 7 shows the mean score, maximum score, minimum score, range, variance, and standard deviation of the researcher's vulnerability findings in comparison to the same information from the findings based on Cutter's social vulnerability equation. It is important to recognize that the researcher's equation produced somewhat different results than did Cutter's (1997) equation for social vulnerability when applied to the Hillsborough County data set. These differences ranged between 0.01 of one vulnerability point to .84 of one vulnerability point, or nearly 1 point out of a possible 7 vulnerability score.

The census blocks with the highest difference in vulnerability scores is shown in Figure 64. These 5 census blocks have a difference of greater than .5 of a vulnerability point. It is important to note that the only characteristics that caused these differences were the non-white vulnerability scores and the renter-occupied housing scores. To this end, the area around The University of South Florida, because of its large renters community, had a higher vulnerability, while the areas of Hillsborough that have high non-white populations were found to have moderately lower vulnerability scores overall. Table 8 shows the characteristics of the five census blocks with the largest difference in scores.

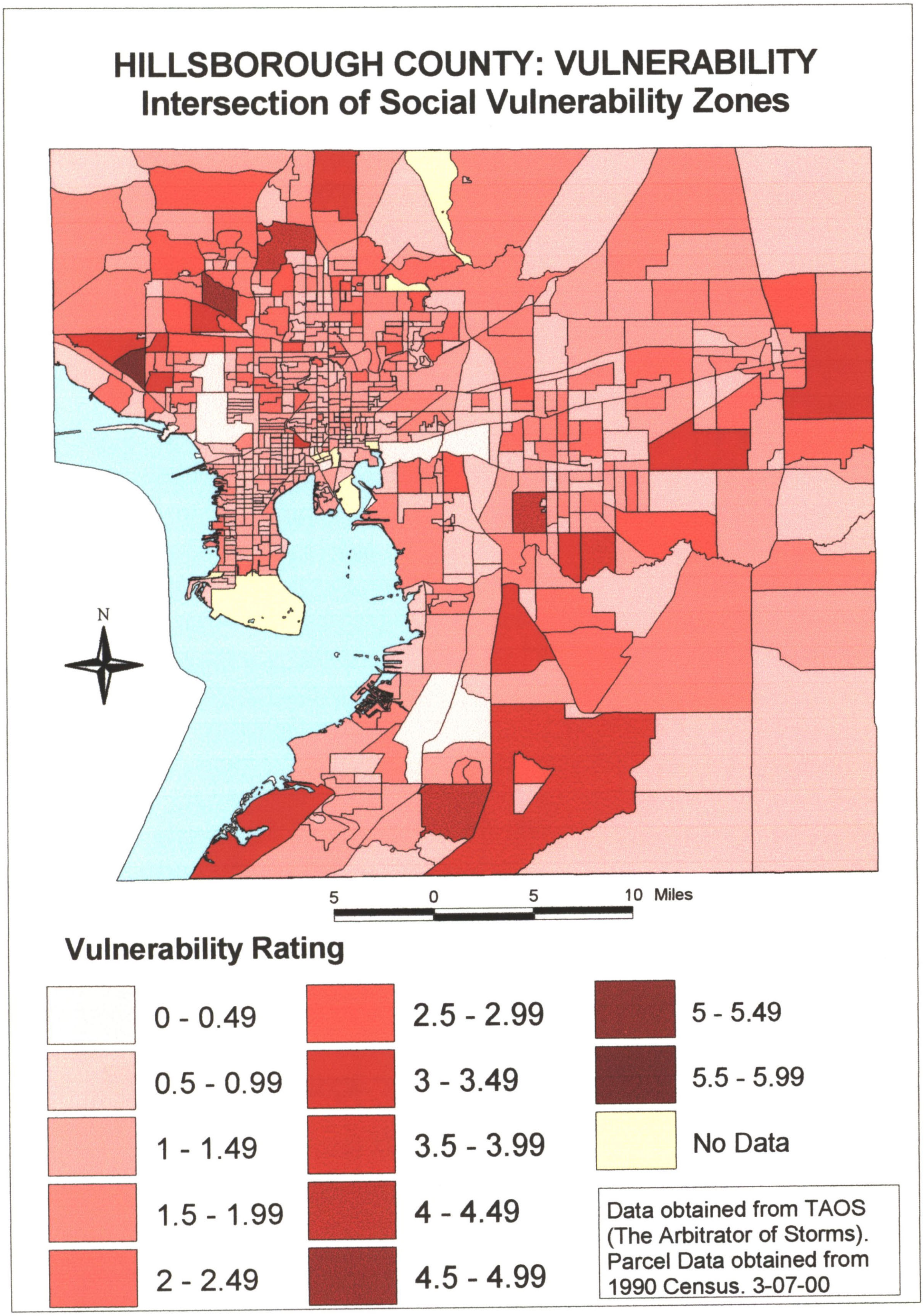

Fig. 63: Hillsborough County - Community vulnerability scores based on vulnerability equation #2.

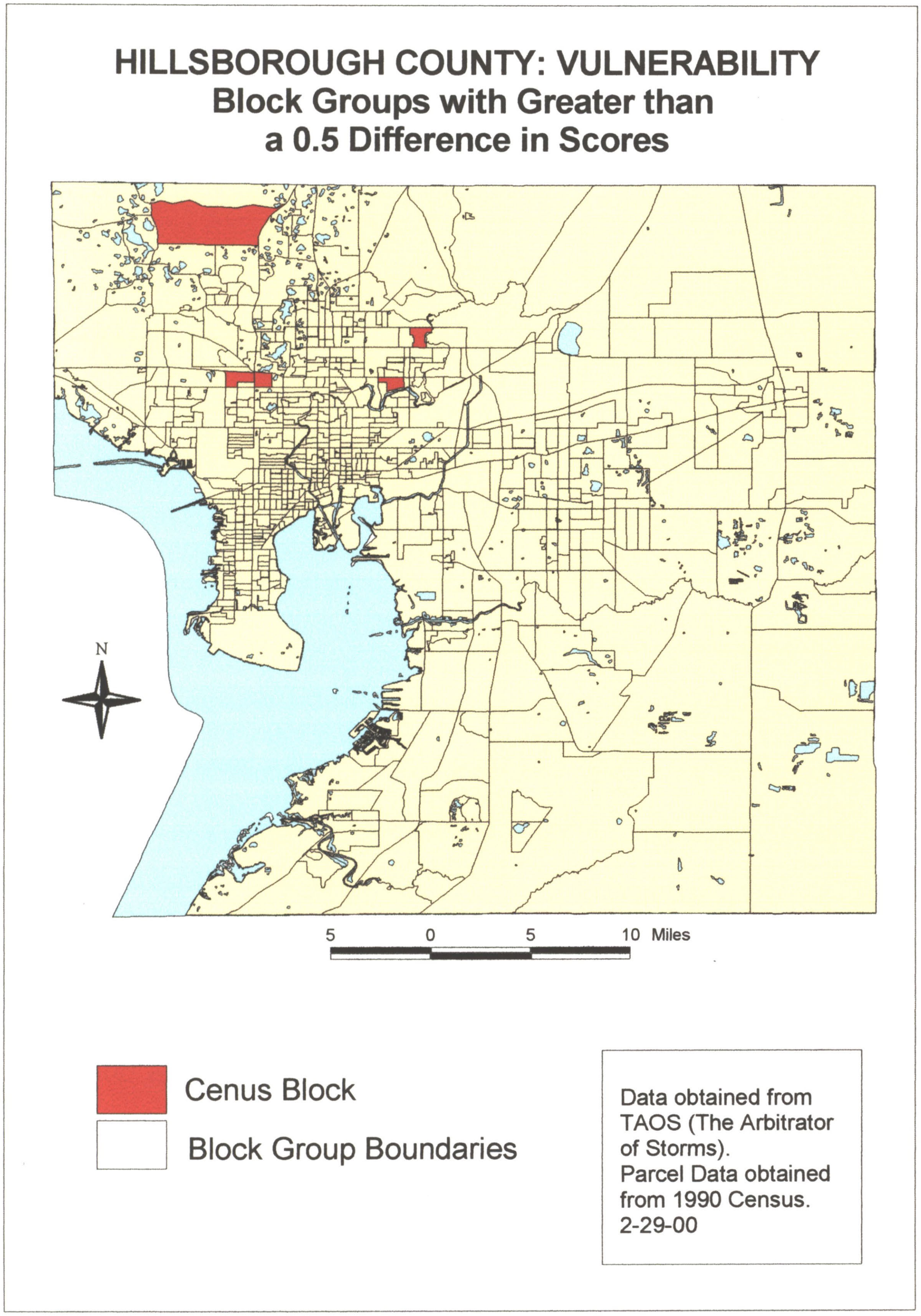

Fig. 64: Hillsborough County - Census blocks exhibiting the greatest difference in vulnerability scores.

Table 7: Hillsborough County - Statistical Comparison of two equations of community vulnerability.

	Vulnerability Score #1	Vulnerability Score #2
Mean Score	1.2	1.19
Maximum Score	5.73	5.94
Minimum Score	0	0
Range	5.73	5.94
Sample Variance	0.48	0.45
Standard Deviation	0.69	0.67

When Community Risk Meets Community Vulnerability

Intersecting the most risky census blocks in Hillsborough County with the blocks that exhibited the highest vulnerability score enabled the research to be focused on those areas that have the greatest potential of being struck by one or more physical events and the least ability to resist, and recover from these events. Five census blocks were found to be part of the most risky and most vulnerable populations. These areas, shown in Figure 65, are located south central, central, and northwest Hillsborough County. They account for 2.77% of the total population, 5.08% of the total land area, and 2.76% of the total households. Table 9 shows the scores for each characteristic of vulnerability as well as the overall vulnerability scores for these census blocks. Note that these areas were delineated based on a multiple hazard risk that includes only the most destructive hurricane event, a category V hurricane. The risk for other areas will increase if less destructive storms are taking into account. Table 10 further delineates the populations effected by each hazard event. This table represents the percentage of each vulnerability characteristic impacted by hazards.

Table 8: Hillsborough County - Characteristics of five census blocks displaying the greatest difference in vulnerability scores.

	Vulnerability Equation #1	Vulnerability Equation #2	Vulnerability Difference	NonWhite Score	Renter Score	Population Score	Mobile Home Score	<18 Score	>65 Score	Female Score	House Value Score	Housing Density Score
Block #1	3.40	2.56	0.84	0.16	1.00	0.46	0.01	0.22	0.09	0.50	0.56	0.56
Block #2	2.99	2.39	0.60	0.19	0.79	0.43	0.00	0.27	0.03	0.46	0.49	0.52
Block #3	3.40	2.87	0.53	0.28	0.81	0.51	0.00	0.38	0.04	0.52	0.56	0.58
Block #4	3.17	2.67	0.50	0.34	0.84	0.44	0.00	0.31	0.03	0.46	0.48	0.60
Block #5	2.70	2.20	0.50	0.27	0.77	0.38	0.01	0.21	0.02	0.39	0.48	0.45

Figures 66 through 70 depict, in greater detail, those census blocks that the were delineated as the most risky and most vulnerable.

Table 9: Hillsborough County - Vulnerability scores and hazard total for census blocks at most risk and most vulnerable to multiple hazards

	Population. Score	House Value Score	House Score	Mobile Home Score	Under 18 Score	Over 65 Score	Female Score	Renter Score	Overall Score	# of Hazards
Block #1	0.86	0.51	0.70	0.05	0.87	0.08	0.85	0.51	4.43	7
Block #2	0.73	0.51	1.00	0.02	0.01	1.00	0.82	0.11	4.20	7
Block #3	0.68	0.50	0.56	0.00	0.50	0.14	0.68	0.43	3.49	7
Block #4	0.63	0.55	0.41	0.02	0.81	0.04	0.61	0.22	3.29	7
Block #5	0.49	0.48	0.42	0.22	0.46	0.15	0.52	0.46	3.20	7

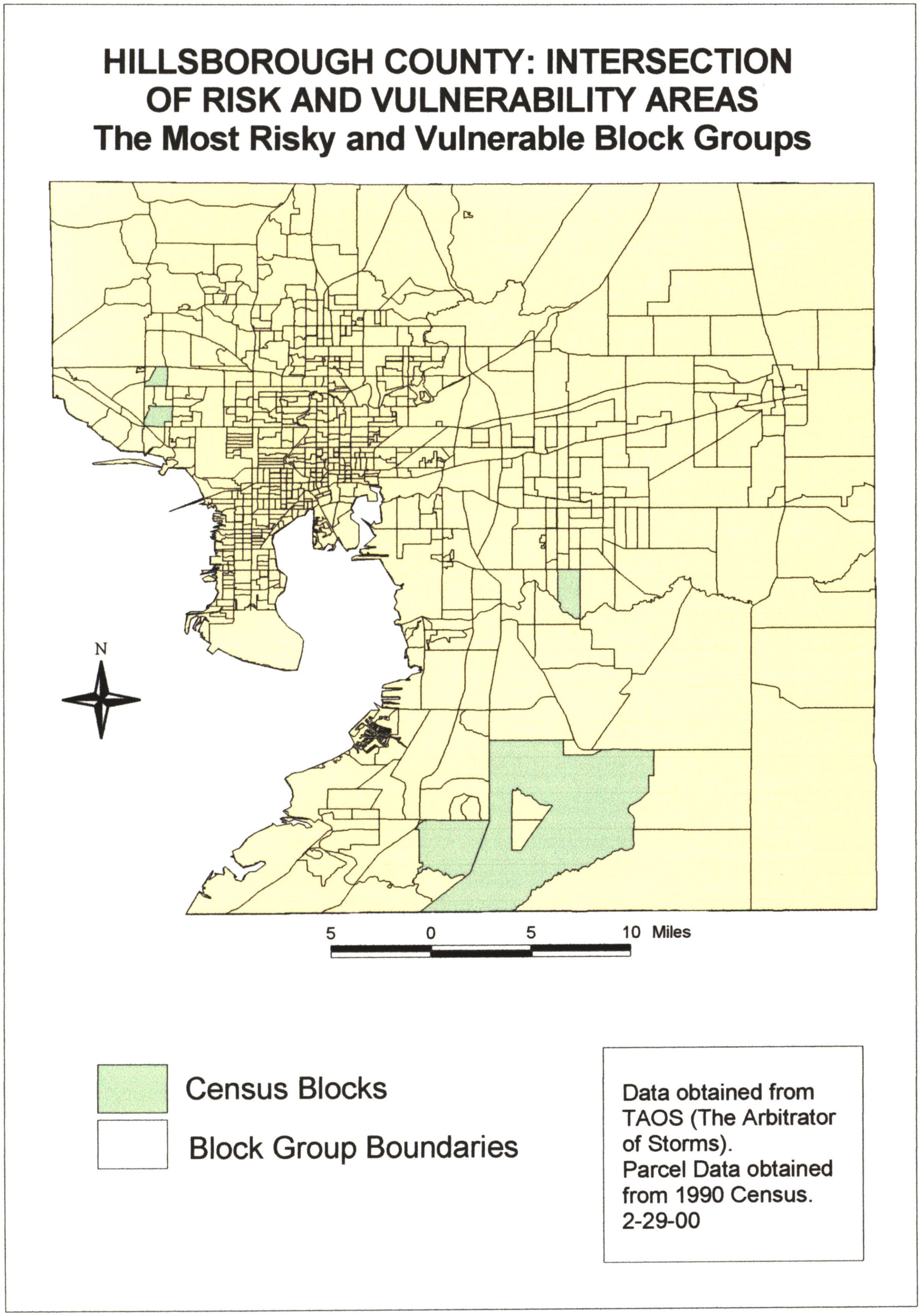

Fig. 65: Hillsborough County - Intersection of high risk and high vulnerability areas.

Table 10: Hillsborough County - Percent of each vulnerability characteristic affected by hazard

Hazard	Area (sq. miles)	Population Density (persons per sq. mile)	Housing Units	Mmobile Homes	Age Under 18	Age Over 65	Female Density	Renter Occupancy
Cat 5 Winds	99.97	99.86	99.86	99.11	99.82	99.83	99.86	99.95
Cat 5 Water	47.42	67.16	69.32	59.92	62.99	72.28	67.03	69.92
Cat 4 Winds	99.84	99.03	99.02	99.09	98.91	99.03	99.01	99.06
Cat 4 Water	39.18	42.76	44.00	52.34	40.10	51.44	42.64	40.39
Cat 3 Winds	99.38	97.83	97.62	97.50	97.84	97.67	97.83	97.50
Cat 3 Water	33.58	35.74	37.26	45.51	32.06	44.80	35.59	34.10
Cat 2 Winds	55.50	34.00	35.25	50.85	31.71	38.70	33.64	50.85
Cat 2 Water	28.98	29.99	31.89	42.35	26.28	39.53	29.80	28.18
Cat 1 Winds	98.49	95.50	95.04	94.94	95.97	94.89	95.40	95.04
Cat 1 Water	24.77	23.96	25.64	35.99	20.70	33.08	23.73	22.24
Trop Winds	100	100	100	100	100	100	100	100
Trop Water	21.23	15.43	17.20	19.91	12.36	23.41	15.14	13.04
Cat 5 S.S.	47.54	47.33	48.39	50.89	45.22	52.67	47.26	44.66
Cat 4 S.S.	46.23	44.91	46.00	49.04	42.48	50.41	44.84	41.79
Cat 3 S.S.	38.34	40.42	41.80	46.73	37.99	45.44	40.34	37.88
Cat 2 S.S.	36.18	36.93	38.52	44.95	34.53	42.56	36.98	33.96
Cat 1 S.S.	33.92	31.82	33.42	38.03	29.30	37.47	31.86	28.24
Trop S.S.	29.90	27.60	29.65	35.86	24.34	34.52	27.80	25.23
Sinkhole	44.86	29.77	28.00	27.57	28.54	24.81	28.59	27.23
Tornado	100	100	100	100	100	100	100	100
100 Year Flood	93.96	72.89	72.34	85.36	72.12	70.24	72.56	67.08
500 Year Flood	96.05	75.43	74.85	87.10	74.65	72.87	75.11	69.54

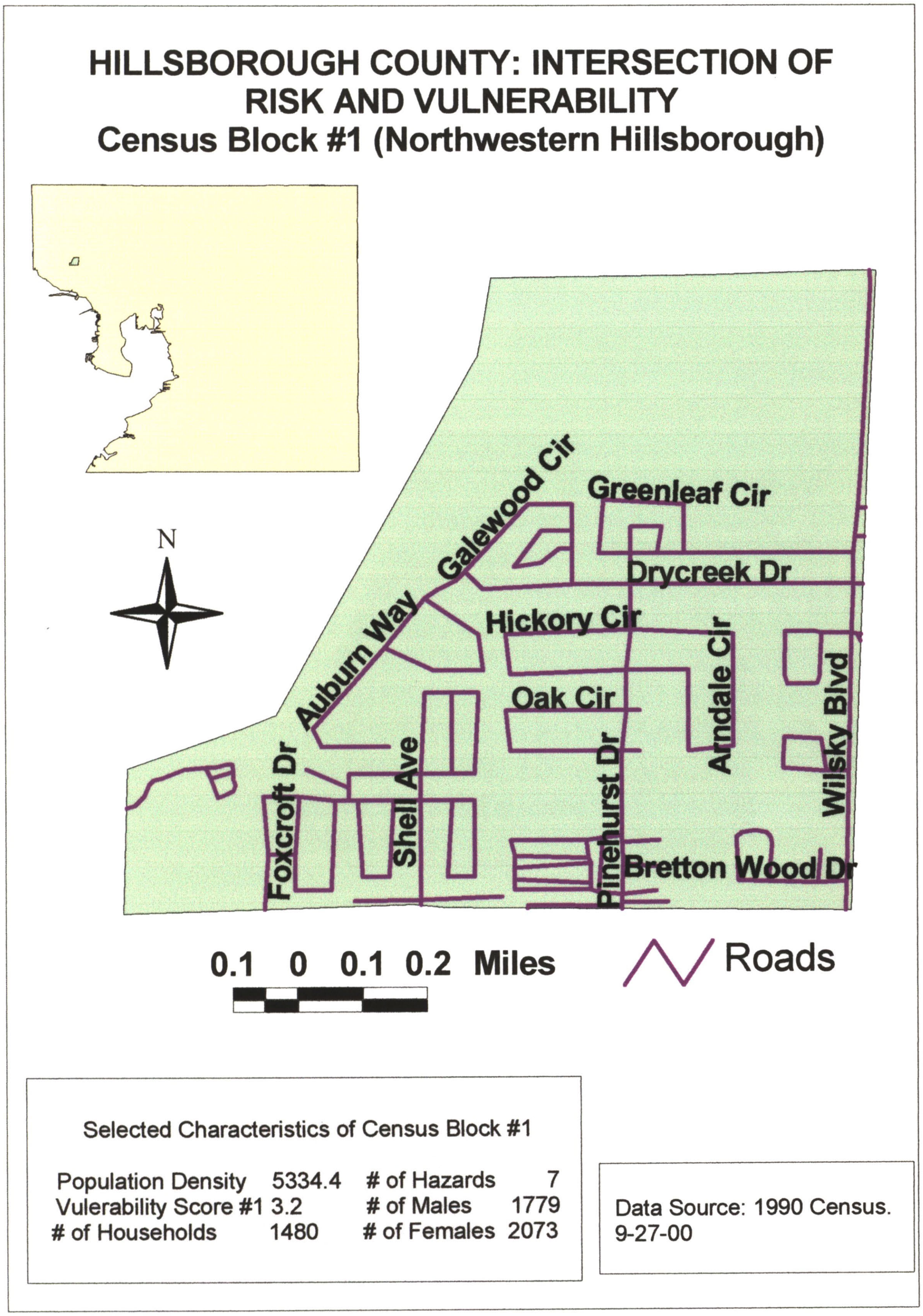

Fig. 66: Hillsborough County - A closer look at high risk and high vulnerability census block #1.

Fig. 67: Hillsborough County - A closer look at high risk and high vulnerability census block #2.

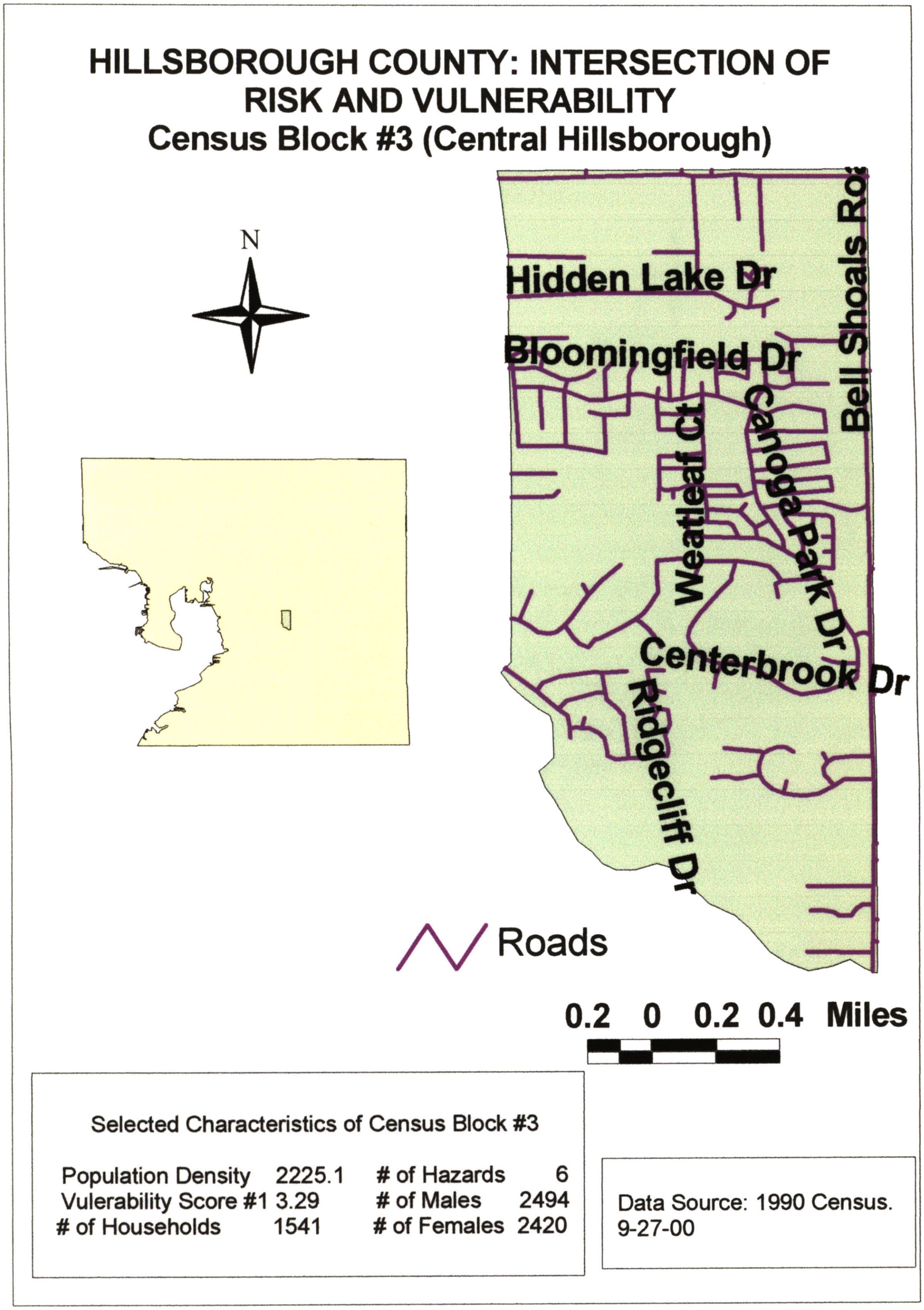

Fig. 68: Hillsborough County - A closer look at high risk and high vulnerability census block #3.

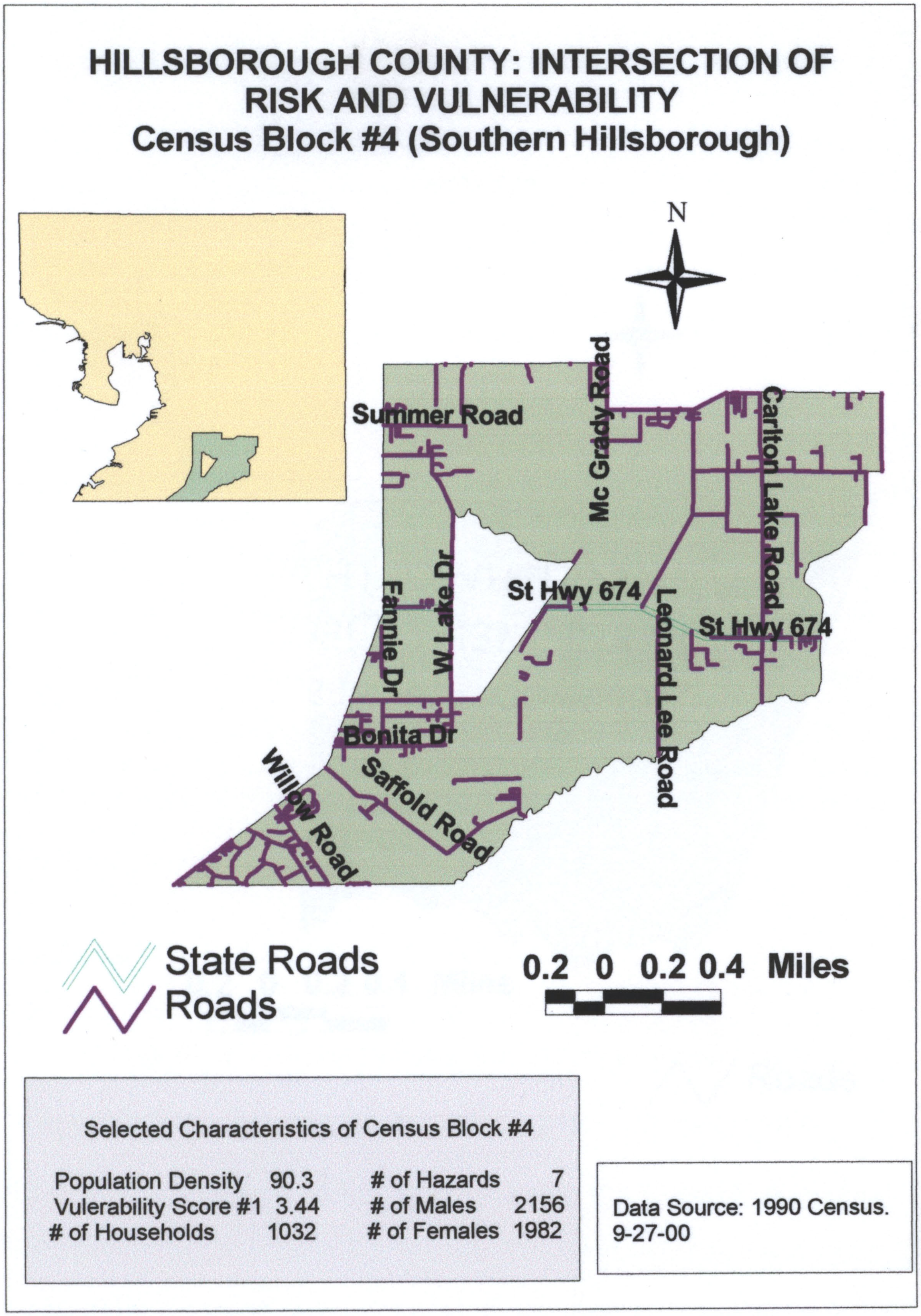

Fig. 69: Hillsborough County - A closer look at high risk and high vulnerability census block #4.

Fig. 70: Hillsborough County - A closer look at high risk and high vulnerability census block #5.

Chapter Five

Conclusions and Discussions

Introduction

This research was conducted with the hope that a framework for multiple hazard risk and vulnerability assessment would be established. It is expected that, with the help of this methodology, planning, mitigation and preparedness will all become more able to cope with the devastating effects of natural disasters. Such a framework has yet to be fully established, thus difficulties may arise in determining to what extent each element of vulnerability is to be weighted in the model. As with all theories, this vulnerability framework is open to refutation, to the extent that it will become more precise through identification of problem areas.

Conclusions

The first research question examined was, "how have the census blocks in Hillsborough County been classified as at risk to individual and multiple natural hazards?" In an attempt to answer this question, literature in the area of individual and multiple hazard risk assessments was reviewed. To this end, one study was identified as a vulnerability assessment. Upon review, this document was found to be directed more along the lines of a hazard overview, providing statistics of potential and actual damage from various physical and technological hazards that might occur in Hillsborough County. Review of the literature proved that individual census blocks of Hillsborough County had not yet been analyzed in the area of individual or multiple hazard risk.

The second research question examined was, "how have the census blocks of Hillsborough County been assessed for characteristics of vulnerability to the effects of natural hazards?" Again, it was found that this subject had not, to date, been undertaken. Hillsborough County's Hazard Vulnerability Analysis (1984), was an attempt to describe vulnerability, but it did not truly follow what is now known in academic circles as the definition of vulnerability. However, other studies around the country had previously laid the groundwork for such theoretical studies to be undertaken. These include a social vulnerability analyses of Washington (1996), Wyoming (1976), North Dakota (1977), Kitsap County, Washington (1998), and Indianapolis, Indiana (1973). Still more studies have undertaken an approach based on the current definition of vulnerability, attempting to identify the most vulnerable areas and the characteristics that lead to vulnerability. These include a community vulnerability assessment of Indianapolis, Indiana (1973) and Susan Cutter's more recent GIS-Based Hazards Assessment for Georgetown County, South Carolina (1997).

The third research question examined was, "what is the current risk of census blocks in Hillsborough County to individual natural hazards?" Areas of Hillsborough County that are at risk of naturally occurring hazard events were identified through analysis of GIS coverages of Hillsborough County and TAOS coverages. The county's 784 census blocks were found to be potentially affected by numerous hazards, including, but not limited to, hurricane force winds, water and storm surge, the 100 and 500 year flood events, tornadoes and sinkholes. Hillsborough County's location near the coast makes it more vulnerable to tropical cyclones and events that often accompany them. In addition, the relief of Hillsborough County is conducive to riverine flooding and ponding, thus making the flood hazard an event to be mindful of during hazard assessment. The county's underlying limestone leads naturally to the occurrence of sinkholes normally caused by drought conditions as well as large amounts of rainfall.

The fourth research question addressed was, "what is the current risk of census blocks in Hillsborough County to multiple natural hazards?" Overlaying Arc View shape files of the census block impacted by individual hazards enabled the identification of areas that were the most at risk, or the census blocks that would be potentially impacted the most by multiple hazards. The coastal areas were found to be on the top of the list of most hazardous areas, but surprisingly, census blocks in southern and western Hillsborough County were found to exhibit comparably high risk factors.

The fifth research question undertaken was, "what are the most important characteristic that influence vulnerability to individual and multiple natural hazards and which census blocks are identified as being the most vulnerable based on these characteristics?" Identification of the key characteristics that help to increase or decrease community response, resistance and recovery to natural hazards and disasters was made possible through the availability of 1990 census data and recent literature on the issue of vulnerability. In addition, the exact census blocks that displayed social characteristics that would detrimentally affect vulnerability were pinpointed through the use of geographic information systems. Also addressed were the variable results that different equations of vulnerability had on the analysis of Hillsborough County.

This research attempted to determine which social characteristics should be involved in the evaluation of community vulnerability. Research has identified a broad variety of factors, including social relations (particularly race, ethnicity, class, and gender), institutional characteristics, demographic attributes (such as age and reproductive status), individual decision making and perception, types of technology employed and political-economic relations that may well contribute to vulnerability (Cannon 1994, Downing 1991, Liverman 1990). To this end, the factors chosen during this analysis of vulnerability will be discussed here as they pertain to the overall community vulnerability to natural hazards in Hillsborough County.

Median house value, acting as a surrogate for income, serves as an indicator of the ability to resist and be resilient in the face of natural hazards. Income, or in this case median house value, was thought to be inversely related to vulnerability. The census block groups of the county were predominantly found to have high median house value vulnerability scores. These scores indicate that the communities of Hillsborough County will be at greater vulnerability to natural hazards because of a possible lack of resources that would enable a quick and effective "return to normalcy". These high scores could have the potential to skew the overall vulnerability scores for the county if income is found to be less important a determination of vulnerability. Previously, studies have shown that poverty and exposure to hazards are seen only as rough surrogates for a more detailed understanding of vulnerability (Dow 1992). This statement provides additional thought into the area of weighting, in order to give characteristics proper representation in a true equation of vulnerability. Median house value alone shows the amount of money that is being spent on housing, but it does not properly reveal vulnerability.

Gender, or more accurately, females are usually more at risk and more vulnerable to hazards and disasters than their male counterparts. The historical role of women as primary family caregivers contributes to their exposure to disaster (Fothergill, 1996). Women are believed to be more vulnerable because they are often less wealthy than men. Women disproportionally live in poverty in the United States and worldwide and female headed single parent households have a poverty rate four times that of male-headed households (Fothergill, 1996). In this research, gender was thought to be positively linked with vulnerability. The extent to which gender acts as an indicator of vulnerability is an unknown, yet a basic measure of vulnerability would be incomplete without the inclusion of gender characteristics. Areas in Hillsborough County with high female vulnerability scores were found to corresponded to areas that had higher scores in other vulnerability characteristics.

Age dependent populations, both under age 18 and over age 65, have been linked to vulnerability. Lack of mobility, frequently coupled with lower income rates, often renders older persons less able to resist hazards. In addition, younger people are sometimes seen as having increased vulnerability because of a lack of resources and dependence on guardians for safety and security. These facts often place younger persons in situations to which they cannot properly respond. This study recognizes that younger and older persons are less able to respond to disaster events and thus are more vulnerable to the affects of such events. The areas of Hillsborough County that have higher under 18 vulnerability scores also correspond to the areas in the county that exhibit higher vulnerability scores from other social characteristics. Because of current positive trends in the job market of the Tampa Bay area, new families are able to raise children. This leads to increases in under-aged persons, thus making these communities more vulnerable to hazard events. In contrast, the number of over 65 dependents in Hillsborough County seems to have less of an impact into the overall vulnerability of the county. With only a few areas containing higher rates of older persons, the county as a whole does not exhibit greater vulnerability to hazards due to higher populations of elderly persons. Although older persons do not heavily influence community vulnerability in Hillsborough County, it is important to note that other places that may implement similar research will find that older dependent populations occur in areas where higher scores exist from other social characteristics.

Population Density plays a large role in the determination of vulnerable communities. Ever increasing interest in development along the Gulf Coast and new, state of the art, communities across the Tampa Bay area attract more and more people every day. This increase in population potentially puts more people at risk to naturally occurring hazards. During these events, increased numbers of people essentially equal fewer resources per person, thus less ability to recover from the disaster event. Population density was thought to be a social factor that would be positively related to community vulnerability. The areas of high population density scores were found to correspond to areas that exhibit higher scores from other social vulnerability characteristics.

Housing Type, or persons residing in lower quality housing, such as mobile homes, were seen as more vulnerable to hazards. The lower grade construction of mobile homes and subsequent inability to withstand high winds places the occupants of such housing high on the list of vulnerable persons. Fortunately, Hillsborough County does not have large numbers of mobile homes in regards to total homes. Thus, in regards to the county, mobile home vulnerability scores do not play a large role in higher overall vulnerability scores. It is important to note, however, that counties with greater numbers of mobile homes will have higher overall vulnerability.

Housing Density, as discussed earlier, is believed to be an indicator of increased vulnerability to natural hazards. Increased development lowers the natural environment's ability to cope with and be effectively resilient to natural hazards. This being the case, even small scale events can have greater impact on an area if development has impaired nature's ability to respond to the hazard. Housing density vulnerability scores are moderate throughout the county, yet areas exhibiting higher scores appear to be consistent with areas of the county found to have higher scores for other characteristics of vulnerability.

Renter Occupancy is found to be an indicator of more vulnerable populations. It has been shown that persons who rent housing normally do not procure renter's insurance policies. This lack of insurance on personal property has been shown to be detrimental in the case of hazards. Normally, renters to not have adequate enough assets to foster a proper recovery from disaster events. They must start again on the bottom rung of an economic ladder that often seems to be never ending. To this end, persons who reside in renter occupied housing are believed to be more vulnerable to hazards than those who own their residences. The areas of the county that are found to have high renter occupied housing scores are consistent with areas of the county found to have higher scores for other characteristics of vulnerability.

The final research question was aimed at identifying the census blocks of Hillsborough County that were the most at risk and the most vulnerable. This task was accomplished through the use of GIS selections and overlays. Although relatively few census blocks were identified in this area of study, the concern that even these were identified remains at the forefront of this research.

Discussions

An estimated 1 million people have died in the past 20 years from earthquakes, 2 million more have died in other natural hazards and 1 billion have been permanently injured or left homeless by catastrophes-- losses that could have been substantially reduced by preventive planning (Shannon 1989). "In the United States, people are becoming increasingly vulnerable to natural hazards, disaster-caused losses are rising and federal assistance programs expanding. The predominant Federal investment in natural hazards research is in studies which enforce rather than reduce the likelihood of catastrophe." (White and Haas 1975, 1) There have been hazard reduction proposals and efforts, but the inevitability remains, "Hazards cannot be prevented", but their impacts can be lessened in various ways (Coppock 1995, p22). Although relatively little has been done in relation to the economic, social and political aspects of adjustment to natural hazards, social characteristics of vulnerability are important in proposing hazard reduction alternatives where mitigation normally takes the form of structural (engineered) approaches to hazard reduction (Cutter 1996).

> Redirection of Federally funded natural hazards activity could sharply reduce human suffering, substantially curb the nation's annual billion-dollar disaster-caused economic losses, and bring

> about a marked reduction in Federal and State expenditures required to cope with such losses. It could halt the rising trend in property damages, and also reduce the social disruption and secondary losses to the total economy caused by interruptions in production, transportation and communications facilities (White and Haas 1975, 1).

In the case of this research, many points made by authors on the subject of hazards research and vulnerability reduction can be developed further. For instance, Mileti, 1999, summarizes a need for hazards research that includes:

- A comprehensive database that contains information about current levels of vulnerability to natural hazards on national and local scales.

Hillsborough County will benefit from the knowledge gained during the process undertaken in this research. There is now a set of data for Hillsborough County that takes into account current levels of vulnerability to individual and multiple natural hazards. The research undertaken here can be applied to other data sets in an effort to establish an all encompassing database in the field of vulnerability research.

- An integrated accessible database of losses and vulnerabilities could create a feedback loop between communities, researchers, regulatory agencies, emergency managers, the insurance industry, and others to improve overall effectiveness in coping with hazards and disasters.

Currently, in Hillsborough County there is a hazards mitigation working group that could use the data generated in this research to expand it's current implementation of policies and protocols for emergency events. The use of these data has the capacity to link other agencies, the insurance industry and even residents in order to reduce vulnerability to naturally occurring hazards.

- Innovative mitigation activities, which have been developed and implemented since 1975 to lessen some community's vulnerability to natural disasters.

Hillsborough County has already implemented hazard mitigation strategies for the present and future. Hopefully, this research can add to the knowledge used to generate such strategies, making them more effective and eventually allowing for locally imposed variations on these plans that assist communities more proficiently.

- Vulnerability as the measure of the capacity to weather, resist, or recover from the impacts of a hazard in the long term as well as the short term.

The findings of this research will allow for the adjustment of policies and regulations that could reduce vulnerability to hazards before, during and after the disaster event.

- Focus on characteristics of people and the groups in which they live as a major system that interacts with others to determine disaster losses (Mileti 1999).

This research was undertaken in order to identify the social characteristics of communities that could be studied and possibly adjusted in order to combat destruction and loss from natural disasters.

In addition to Mileti (1999), White and Haas (1975) propose that research could help reduce potential vulnerability to and costs of natural hazards by:

- Increasing national economic efficiency through heavier reliance upon individual choices within guidelines intended to prevent vulnerability to greater catastrophes;
- Enhancing human health through better warning systems, consumer protection and increased preparedness for emergency action;

This research will allow the citizens of Hillsborough County to understand the hazards that can be expected in this area. Citizens have a better chance to prepare for hazards and disasters and cope with the effects of such hazards if information on the current state of risk is made available to them.

- Avoiding national disruption by focusing on ways to reduce catastrophe potential;

This research gives policy makers and planners a fresh look at the potential for hazards that face Hillsborough County. Through the application of these findings, new policies and strategies can be put into effect in order to help reduce potential catastrophes.

- Creating more equitable distribution of costs and benefits of recovery through programs which provide benefits more equally among various economic and social groups;

The data analyzed in this research point to certain groups that should be looked at as more vulnerable. These groups of people and communities will benefit in the long run if recovery practices and programs take the information formulated through this research and apply it to disaster recovery protocol.

- Slowing down further modification of ecosystems and atmospheric circulation to maintain environmental quality and preserve broad options in further use and protection of natural landscapes.

As shown in this research, the areas of greatest risk and vulnerability are often those found in the areas of greatest new development or over development. Zoning practices and perhaps caps on development would decrease the amount of people residing in hazardous areas, allowing communities to be somewhat more resilient to natural disasters. If policies and practices in social, political and economic frameworks were to be amended, perhaps the populations that are currently vulnerable to natural hazards will become increasingly more able to withstand and even overcome disaster more easily.

Along these lines, Hillsborough County is currently involved in a mitigation effort known as 'Project Impact', sponsored by the Federal Emergency Management Agency (FEMA). The Tampa Bay area was selected for Project Impact because of the region's high potential for damage from (Newman, 1999). The project operates on a commonsense damamge-reduction approach, basing its work and planning on three simple principles: First, prevention actions must be decided at the local level; second, private sector participation is vital; and third, long-term effects and investments in prevention measures are essential. The incentive from this disaster approach is clear. A disaster resistant community is able to bounce back from natural disaster with far less loss of property and consequently much less cost for repairs. Moreover, the time lost from productive activity is minimized for both businesses and their employees.

Academics, planners and researchers should continue to analyze the characteristics of populations that might lead them to be more vulnerable. In addition to this research, perhaps statistical connections can be made between social characteristics and community vulnerability. These connections could call for certain weighting procedures in order to form a more accurate equation of overall community vulnerability. Such a weighted framework would enable an understanding of vulnerability to hazards that could facilitate slight changes in the social system that would eventually decrease community vulnerability. This framework, however, needs to be tested in different environments in order to validate the accuracy of the vulnerability measure

Unfortunately, research today seems focused largely on technological oriented solutions to problems of natural hazards instead of focusing equally on the social, economic and political factors which lead to non adaptation of technological findings, or which indicate that proposed steps would not work or would only tend to perpetuate and increase the problem. In short, the all-important social, economic and political "people" factors involved in hazards reduction have been largely ignored. They need to be examined in harmony with physical and technological factors. The key to a more hopeful future is establishing long term thought and taking effective steps before a hazard event in order to reduce risk and vulnerability. Indeed, it is the social, economic and political factors that need to be addressed, since they have contributed to the generation of the hazards in the first place.

In the case of Hillsborough County, this may equate to changing the policies that might lessen the potential vulnerability of people. Changes in policies on land use, rental insurance, housing structure, and health care would make a positive difference in the vulnerability of everyone. This means helping city governments to plan and take the necessary actions with the involvement of the local people and the business community (Mustow 1999).

References

Alexander, D. (1991). Applied Geomorphology and Impact of Natural Hazards on the Built Environment. *Natural Hazards*, 4 (1): 57-80.

Alexander, D. (1997). The Study of Natural Disasters, 1977-1997: Some Reflections on a Changing Field of Knowledge. *Disasters*, 21, 284-304.

Ansell, J., & Wharton, F. (1992). *Risk: Analysis, Assessment and Management.* New York: John Wiley & Sons.

Associated Press, Development increases disaster vulnerability. May 20, 1999. *The Boston Globe.* National/Foriegn p.A11.

Baker, G.W. & Chapman D.W.(eds.). (1962). *Mankind and Society in Disaster.* New York: Basic Books Inc.

Blaikie, P., Cannon, T., Davis, I., & Wisner B. (1994). *At Risk: Natural Hazards, People's Vulnerability, and Disasters.* New York: Routledge.

Bolin, R., & Bolton, P. (1986). *Race, Religion, and Ethnicity in Disaster Recovery.* Boulder, Colorado: Institute of Behavioral Science, The University of Colorado.

Bolin, R. & Stenford, L. (1998). The Northridge Earthquake: Community-based Approaches to Unmet Recovery Needs. *Disasters*, 22(1): 21-38.

Burby, R.J. (Ed.) (1998). *Cooperating With Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities.* Washington D.C.: Joseph Henry.

Burton, I., Kates, R.W., & White, G.F. (1993). *The Environment as Hazard.* New York: Guilford.

Chang, T., Yiak, K., Pezeshk, S., & Kung, H. (1993). *Inventory and Preliminary Seismic Vulnerability Assessments of Essential Facilities in West Tennessee.* Center for Earthquake Research and Information, Memphis State University, Memphis, Tennessee.

Cothern, C.R. (Ed.) (1993). *Comparative Environmental Risk Assessment*. Boca Raton: Lewis.

Covello, V.T., & Merkhofer, M.W. (1993). *Risk Assessment Methods: Approaches for Assessing Health and Environmental Risks*. New York: Plenum.

Covello, V.T., Flamm, W.G., Rodricks, J.V., & Tardiff, R.G. (Eds.) (1983). *The Analysis of Actual Versus Perceived Risks*. New York: Plenum.

Crouch, E.A.C., & Wilson, R. (1982). *Risk / Benefit Analysis*. Cambridge: Ballinger.

Crozier, M. (1988). The Terminology of 'Natural Hazard' Assessment. *New Zealand Journal of Geography*, 86, 5-7.

Cutter, S.L. (Ed.) (1994). Environmental Risks and Hazards. New Jersey: Prentice-Hall.

Cutter, S.L. (1996). Societal Responses to Environmental Hazards. *International Social Science Journal*. 48, 525-537.

Cutter, S.L., Mitchell, J.T., Scott, M.S., & Thomas, D.S. (1997). *A GIS-BAsed Hazards Assessment for Georgetown County*, South Carolina. Department of Geography, University of South Carolina.

Cutter, S.L., Mitchell, J.T., & Scott, M.S. (1999). *Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina.* Department of Geography, University of South Carolina.

Dershem, L., & Gzirishvili D. (1998). Informal Social Support Networks and Household Vulnerability: Empirical Findings From Georgia. *World Development*. Vol. 26, No. 10, pp. 1827-1838.

Dow, K. (1992). Exploring Differences in Our Common Future(s): the Meaning of Vulnerability to Global Environmental Change. *Geoforum*, Vol. 23, No. 3, pp. 417-436.

El-Sabh, M.I. & Murty, T.S. (Eds.) (1988). *Natural and Man-made Hazards*. Boston: D. Reidel.

Elsner, J.B. & Kara A.B. (1999). Hurricanes of the North Atlantic: *Climate and Society*. New York: Oxford University Press.

Fischhoff, B., Lichtenstein, S., Slovic, P., Derby, S.L., & Keeney, R.L., (1981) *Acceptable Risk*. Cambridge: University.

Fothergill, A. (1996). Gender, Risk, and Disaster. *International Journal of Mass Emergencies and Disasters*. Vol. 14, No. 1, pp. 33-56.

Fuher, E.J., Scott, P.M., Miller, P.C., & Parlow, L.D.(1977). *North Dakota Hazard Vulnerability Analysis.* Disaster Emergency Services Planning Section, Bismarck, North Dakota.

Garrick, B.J., & Gekler W.C. (Eds.) (1991). *The Analysis, Communication, and Perception of Risk.* New York: Plenum.

Glass, R.I., Craven, R.B., Bregman, D.J., Stoll, B.J., Horowitz, N., Kerndt, P., & Winkle, J. (1980). Injuries from the Wichita Falls Tornado: Implications for Prevention. *Science*. 207: 734-738.

Glickman, T.S., & Gough, M. (Eds.) (1990). *Readings in Risk.* Washington D.C.: Resources for the Future.

Hertz, D., & Thomas, H. (1984). *Practical Risk Analysis: An Approach Through Case Histories*. New York: John Wiley & Sons.

Hewitt, K., & Burton, I. (1971). *The Hazardousness of Place: A Regional Ecology of Damaging Events*. Toronto: University of Toronto Press.

Hewitt, K. (1997). *Regions of Risk: A geographical Introduction to Disasters*. Singapore: Longman.

Hillsborough County, Florida. Government Online: Community Statistics. http://www.hillsboroughcounty.org/com_stats/links.html.

Hillsborough County, Florida. Government Online: Boards and Councils. Health Council of West Central Florida, Inc. http://www.hillsboroughcounty.org/bds_coun/healthcouncil.html

Hillsborough County Hazard Vulnerability Analysis. (1984).

Jacobs, T.L., & Vesilind, P.A. (1992). Probabilistic environmental risk of harzardous materials. *Journal of Environmental Engineering*. 118(6): 878-889.

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

Kitsap County Hazard Vulnerability Analysis. (1998). Kitsap County Department of Emergency Management, Bremerton, Washington.

Lave, L.B. (Ed.) (1982). *Quantitative Risk Assessment in Regulation.* Washington D.C.: The Brookings Institution.

Lave, L.B. (Ed.) (1987). *Risk Assessment and Management.* New York, Plenum.

League of the Red Cross and Red Creasant Societies. (1991). *Working with Women in Emergency Relief and Rehabilitation Programmes.* Field Studies Paper No. 2. Geneva, Switzerland.

Longhurst, R. (1995). The Assessment of Community Vulnerability in Hazard Prone Areas. *Disasters*, 19, 269-276.

Mileti, D. (1997). Designing Disasters: Determining Our Future Vulnerability. *Natural Hazards Observer*, 22, 1-3.

Mileti, D. (1999). *Disasters by Design.* Washington: John Henry Press.

Montz, B.E. (1994). *Methodologies for Analysis of Multiple Hazard Probabilities: An Application in Rotorua, New Zealand.* Fulbright Research Scholar Report. Prepared for the Centre for Environmental and Resource Studies, University of Waikato, Hamilton, New Zealand.

Montz, B.E. (2000). The Hazardousness of Place: Risk form Multiple Natural Hazards. Papers and Proceedings of the Applied Geography Conference. V.23. Applied Geography Conferences, Inc.

Morgan, G.M. (1993). Risk Analysis and Management. *Scientific American*, July 1993: 31-41.

Morrow, B.H., & Enarson, E. (1994). *Making the Case for Gendered Disaster Research.* Paper presented to the XIIIth World Congress for Sociology. Bielefeld, Germany: July 19th.

Mustafa, D. (1998). Structural Causes of Vulnerability to Flood Hazard in Pakistan. *Economic Geography*, 74, 289-306.

Mustow, S. Letters: Turkey's Disaster. *The London Independent.* August 19, 1999. Section, Feature. p.2

Newman, J. Disaster Program Includes Pinellas. *St. Petersburg Times.* November 03, 1999. Neighborhood Times, p3.

O'Keefe, P., Westgate, K., & B.Wisner. (1976). Taking the naturalness out of Natural Disasters. *Nature.* Vol. 260, p.566-567.

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

Panizza, M. (1991). Geomorphology and Seismic Risk. *Earth Science Reviews*, 31, 43-54.

Parr, A. R. (1987). Disasters and Disabled Persons: an examination of the safety needs of a neglected minority, *Disasters*, 11 (2), pp. 148-159.

Petak, W.J. & Atkisson, A.A.(1982). *Natural Hazard Risk Assessment and Public Policy*. New York: Springer-Verlag.

Petak, W., Atkisson, A., & Gleye, P. (1978). *Natural Hazards: A Public Policy Assessment*. Redondo Beach, California: J.H. Wiggins Company.

Ritter, D. (1981). *Risk Analysis Research and Demonstration Act of 1981*. 97th Congress. H.R. 3441.

Rubin, C.B. (1998). *What hazards and Disasters are Likely in the 21st Century - or* Sooner*?* Natural Hazards Research and Applications Information Center. Institute of Behavior Sciences, Univerisity of Colorado.

Russell, M. & Gruber, M. (1987). Risk Assessment in Environmental Policy-Making. *Science*, 236, 286-290.

Schroeder, R.A. (1987). *Gender Vulnerability to Drought: A Case Study of the Hausa Social Environment*. Working Paper No. 58, Institute of Behavioral Sciences, University of Colorado, Boulder, CO.

Shannon, D. Mobilization to Lower Disaster Toll Urged; Catastrophes: A Team of Experts Informs the United Nations that Preventive Measures Will Require More Emphasis in the 1990's. *Los Angeles Times*, October 22, 1989. Part A page 47; Column 2.

Singleton, W.T., & Hovden, J. (Eds.) (1987). *Risk and Decisions*. New York: John Wiley & Sons.

Sinkhole Development in Hillsborough County. (1996). Subsurface Evaluations Incorporated. Winter Springs Florida.

Smith, K. (1996). *Environmental Hazards: Assessing Risk and Reducing Disaster*. New York: Routledge.

State of Washington Hazard Identification Vulnerability Analysis. (1996). Emergency Management, Washington State Military Department, Olympia, Washington.

Susman, P. O'Keefe, P. & Wisner, B. (1983). Global Disasters, and radical interpretation. In K. Hewitt (ed.), *Interpretations of Calamity, The Risks and Hazards Series*. Boston: I. Allen and Unwin. p. 263-283.

Tobin G.A, & Montz, B.E. (1997). *Natural Hazards: Explanation and Integration.* New York: Guilford.

Uitto, J. (1998). The Geography of Disaster Vulnerability in Megacities: A Theoretical Framework. Applied Geography, Vol. 18, No. 1, pp. 7-16

UNDRO (1982). Natural Disaster and Vulnerability Analysis. Office of the UN Disaster Relief Co-ordinator, Geneva.

Whipple, C. (Ed.) (1987). *De Minimis Risk.* New York: Plenum.

White, G.F. & Haas, J.E. (1975). *Assessment of research on natural hazards.* MIT Press: Cambridge, Mass.

Wyoming Disaster Preparedness Program Hazard/Vulnerability Study. (1976). Wyoming Disaster Planning Division, Wyoming.

Zenter, R. (1979). Hazards in the Chemical Industry. *Chemical Engineering News* 57 (45), 25-27 and 30-34.