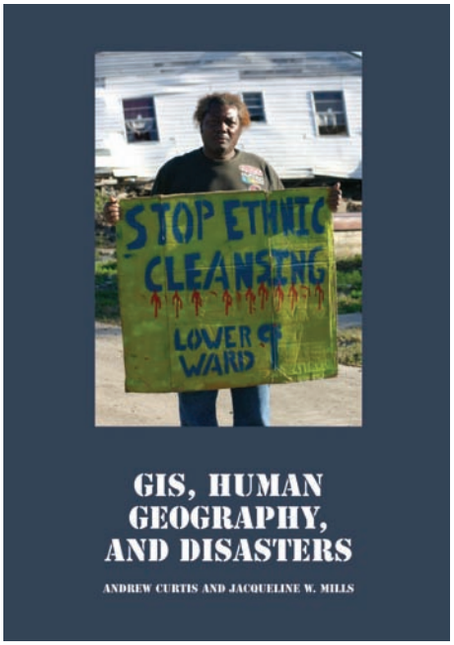

GIS, Human Geography, and Disasters

Andrew Curtis and Jacqueline W. Mills

Included in this preview:

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- Excerpt of Chapter 1

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GIS, Human Geography, and Disasters

by Andrew Curtis and Jacqueline W. Mills

University of Southern California
California State University, Long Beach

cognella™
San Diego, CA

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Introduction

> "Their cardboard city was destroyed by a storm on the afternoon it was completed. What they had built was left in a soggy, formless mess like the city they left behind."—From Chapter Eight: *Art Therapy and Hurricane Katrina*

THE FRONT COVER is a powerful image, and at first glance a casual observer may assume this book is only about racial issues in disasters or surrounding Katrina in particular. This book is about race, but it is also about health, environment, community, vulnerability, policy, planning, mitigation, response, and recovery. In essence, this book is about the human consequences of disasters. The hurt, pain, grief, and fight for normalcy that a disaster causes are part of this story as is the longevity of this suffering. The photography on the front cover was taken one year after Katrina, and yet this same degree of anger and desperation is found today, in the summer of 2009. Disasters have a long-term impact on people and places. As geographers, we are interested in both. We are interested in the spatial aspects of disasters. Often, studies of disasters occur at the scale of a region, or a city, or even at a planning district level. However, you will find that we focus on much finer scales of the human geography of disasters, such as the neighborhood, the street, a block, and even a single house. Returning to the front cover, although the man in the photograph is making a plea to "stop ethnic cleansing," he is focused not on the State of Louisiana, or the city of New Orleans, but on his neighborhood, the Lower Ninth Ward. This micro-scale geography is a theme that we will return to throughout the book.

This book was written primarily for undergraduates taking a class about disasters, but where the emphasis is placed not so much on the physical processes but on how people shape these events and how these events affect people. Although many other texts focus on the sociology of disasters, there are relatively few books on the human geography of these events. This book has been written to partly fill this gap. It has primarily been written for our students at the University of Southern California, drawing on our extensive field experiences of working with disasters, from the Emergency Operations Center (EOC) to neighborhood recovery. As geographers, we emphasize the spatial, showing how every aspect of a disaster can be

Figure I. *An abandoned building in the Lower 9th Ward—one door is open, vegetation has almost reached the roof on one side, and several search and rescue markings are daubed on the front.* Source: Curtis, June 2009.

Figure II. *A burned out car is abandoned in the road, while at the other end a water- and vegetation-filled pothole make this road in the Lower 9th Ward completely impassible.* Source: Curtis, June 2009.

mapped to more fully understand the processes at work. But again, in keeping with the theme of this book, these maps focus more on the distribution of social, rather than physical processes. In so doing, we also present a different side to many other texts as we stress the local, or using geographic terminology, the fine scale.

This is not to say it isn't important to understand the physical processes at work—it is. We also teach these in our classes, but there are many books that cover these processes, so there is no need for further replication. Although the subject matter draws on all disaster types, both from the past to the present, much of our focus is on Katrina. This is for two reasons. Firstly, this single event has generated more disaster-related discussion—especially from a social perspective—than any other event in recent times. Secondly, we have extensive research experience from the time of landfall to our ongoing collaboration with different New Orleans neighborhoods as they struggle to rebuild their shattered communities.

From this perspective, we are writing about what we know, and not just synthesizing the experiences of others (though obviously this occurs as well). Having said that, we have written this book in such a way that instructors need not have a personal experience with these events; nor is it vital that an instructor has experience with different geospatial technologies. The exercises included in this book can be applied by Geographic Information Systems (GIS) users, but anyone with access to Google Earth can also benefit. In our classes we use these as a spring board for more sophisticated GIS exercises, but these are not included here—we are stressing the human and the spatial, not just data and techniques. We also focus our attention entirely on the United States—and we are the first to admit that a similar book is needed for the many disasters that occur globally every year. But we have tried to concentrate on what we know, and in so doing help improve the students understanding of the complexities involved rather than covering too much material at a shallow level. From the student's perspective, this is not a text full of dates or numbers to memorize for exams. We want you to understand the social processes at work—linked by their geography.

From our perspective, we continue to visit our neighborhood collaborators, taking spatial video, turning these videos into maps for their ongoing fight to return to normalcy. Our last trip in June 2009 covered four of these communities. Unfortunately, for each the return rate is still less than 50% (far lower for some). Some streets are in terrible condition; in some places they are completely impassible. Badly damaged homes, some almost covered with vegetation, fading but still visible search and rescue markings on the walls are evidence their decline, while next door a family bravely tends to a well manicured flower garden. Crime is rampant in many areas. We are often told of the health problems that follow the returnees who are now forced to travel further afield for clinic visits, pharmacies, and some of the basic necessities we all take for granted. The physical anchors of the social

networks so important to these communities, churches, community centers, corner stores, still too often are abandoned. And yet through it all, through the incredible hardship and daily suffering we are constantly amazed by their resolve—to never give up. That is why we continue to go back and do all we can. It is also the reason why we take students with us, because not only is labor needed, but so is education. More people need to learn about this ongoing disaster.

And that is our hope for this book—to not only provide a useful classroom tool to provoke discussion but also educate about the many social aspects of Katrina and disasters of its kind ... and maybe stimulate a few to carry on with work in this area. After every semester we have a few who want to be involved, to spend a spring break rebuilding the homes of Louisiana, to become part of our research team, or even to learn more about art therapy. In this spirit, any royalties from these books will go to a research fund to continue our collaborations with the communities of New Orleans.

Figure III. *Our spatial video system captures an abandoned church, a wooden cross wired to the door. A contact telephone number has been sprayed on the wall.* Source: Curtis, June 2009.

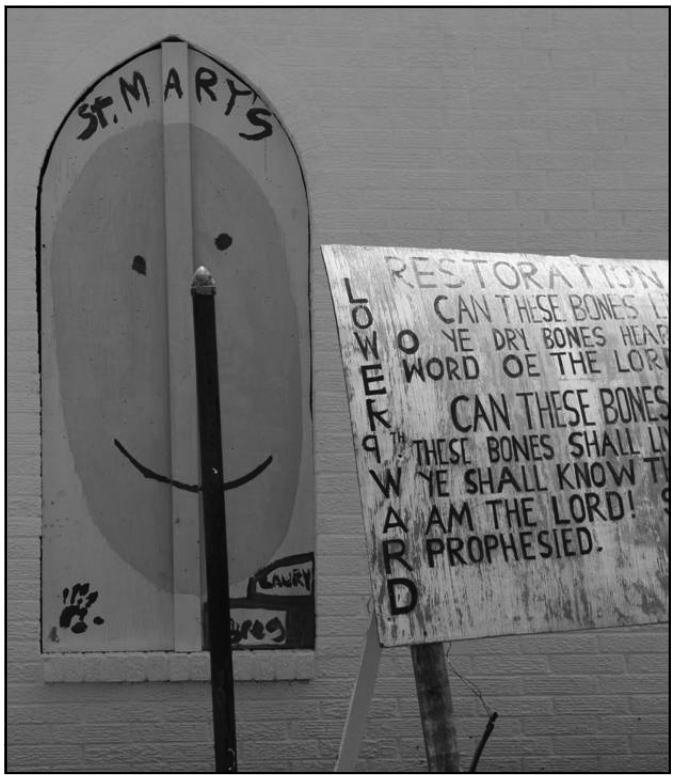


Figure IV: A message of support outside a church is now weather worn. *A smiley face has been painted on the window shutter behind. Readers will find this same scene elsewhere in the book (Figure 9:6), though taken two years earlier—the message of hope a little brighter, and search and rescue markings where the smiley face is.*
Source Curtis, June 2009.

The book is split into five general themes, though these meld between the chapters

1) Understanding why geography is important
2) Comparing the past to the present
3) Issues of vulnerability
4) The psychological impact
5) The road to recovery

In Chapter One, we introduce why geography matters—why various aspects of a disaster are spatial in nature and therefore should be investigated for their underlying spatial processes, and of course be mapped. Some basic spatial concepts are introduced, and an example of application of these concepts is provided through a case study on how to spatially predict the surge potential for a hospital after an earthquake in Los Angeles. The impact Google Earth and Street View have had on information dissemination are mentioned, as is our spatial video system which allows for the collection of post-disaster landscape data. By the end of this chapter, readers unfamiliar with geography, or spatial thinking in general, should have a sense of why a book on *GIS, Human Geography and Disasters* has relevance.

In Chapter Two, we continue this initial exploration of a spatial approach to the human side of disasters by concentrating on the technologies we have at our disposal, especially Geographic information Systems (GIS). The basic components

of a GIS are described, with focus being placed on methods of spatial data input, analysis, and mapping. This chapter spends some time providing examples of different disaster cartographies, including mapping recovery. Both recovery mapping and the spatial video will be returned to in chapter twelve—in effect providing bookends for the reader. By this point the concepts will be familiar, and enriched by the discussion of human impact in intervening chapters.

Chapter Three begins a two part sequence that compares the events of the Johnstown Flood of 1889. The events of this terrible disaster, which have echoes of Katrina in terms of a natural event being compounded by human mistakes, are primarily told using the exact language of a Board of Public Health report. The approach of this chapter gives the reader exposure to another key disaster and allows for comparative discussion points. In order to facilitate this, photographs from Katrina with accompanying descriptions are scattered throughout the chapter at suitable comparative "moments."

Chapter Four continues our comparison of the Johnstown flood with Katrina using the same style as the previous chapter. However, while chapter three concentrated on the description of the actual disaster, chapter four focuses on the post-event response and clean-up stages. The chapter starts with a personal narrative of our first flight over New Orleans and the bayous beyond; it is included to add that human touch, a geographer's description of a devastated landscape.

Chapter Five changes disaster type to California Wildfires, though it maintains a similar presentation approach as Chapters Three and Four in that primary descriptive sources (in this case newspaper stories) are used to convey the human consequences. This chapter also segues between the opening chapters (spatial concepts, use of GIS) to the next section on disproportionate impacts.

The next sequence of chapters describes the social environment that underlies the disproportionate impact of many disasters.

In Chapter Six we further elaborate on the concept of social vulnerability, particularly which groups are known to suffer the brunt of a disaster, why this occurs, and the implications of this spatial pattern. Concepts such as "hazardscape" are introduced through examples that range from a nuclear detonation to Katrina. Cartographic overlays are used as an approach to understand how different geographies can be combined. These overlays compare pre-Katrina vulnerabilities with surfaces depicting various aspects of the disaster; including 911 call data, flood depth and building damage. The result from a more sophisticated analysis of vulnerability measures and flood height is also presented. This chapter provides details on the traditional measures of social vulnerability, even though three of particular relevance to New Orleans are emphasized: race, poverty, and females as head of household.

Chapter Seven continues the discussion of vulnerability by introducing a less well described pre-disaster concern, that of health vulnerability. Although tied closely to social vulnerability, the urban poor—and especially African Americans—carry a high debilitating health burden that not only increases their likelihood of disaster exposure but may also hinder the return to normalcy. Indeed, these chronic conditions may actually worsen and lead to a further widening of the health gap between minorities and whites. Emphasis in the chapter is placed on how single female headed families are of particular concern—using examples of how Katrina may cause future poor birth outcomes in Louisiana, and in so doing leave a health legacy to be borne by future generations. The chapter ends in considerable detail regarding the types of health and social services that were mobilized for evacuees in Baton Rouge after Katrina—these providing the basis for students to understand the post-event complexity of vulnerability.

Continuing with this progression, two guest chapters are included. Chapter Eight describes the work of Karla Leopold, who was part of a team that used Art Therapy to help evacuee children in Renaissance Village, a FEMA trailer park located just outside of Baton Rouge, Louisiana. Every semester Karla gives a guest lecture for me—and she never fails to move the students. From a geographer's perspective, I am always amazed at the spatial nature of the pictures the children produce, and how spatial order is important. I find the stories of the children that accompany these pictures to be extremely moving and important for understanding the mental health consequences of disasters.

Chapter Nine is also primarily written by a guest, Louisa Holmes, who is a senior doctoral student in the Department of Geography at USC. She has considerable experience working in the field of stress and the built environment. She provides a detailed overview of different mental health problems, their causes, manifestations, and coping strategies employed. This is not an easy chapter to read; it is dense and purposefully so. For the sake of brevity we often have to synthesize and therefore simplify information. However, this chapter will give the reader a glimpse of the complexity involved and how the information presented here is actually a thread that can be followed and expanded like a spider's web.

Chapter Ten also contains a section on disaster related psychopathology, using one of the models (conservation of resources) to help explain why so many people spray painted messages across their homes. This chapter looks at the post-disaster landscape from this perspective, not in terms of the damage wrought, but by the human markings left behind. We show how a GIS can be used to collate all these messages, especially the search and rescue crosses. Very little has been written about this marking of a landscape which is so visually arresting.

Chapter Eleven provides an overview of our current understanding of recovery, the multiple spatial scales where this process occurs, and the importance of planning

for recovery. In addition, new forms of geospatial data collection are described as tools that allow researchers or communities to collect recovery data that can be linked to a GPS, mapped, and used as a management and advocacy tool.

Chapter Twelve brings together several of the themes described through the book in a description of our collaborative work with Churches Supporting Churches in New Orleans. We again return to the spatial video, describing in more detail how it works, from a technical perspective to the way in which we encode information from the video into a GIS. Different classification schemes are presented, as are examples of our neighborhood maps. This chapter ends with as series of exercises utilizing Google Street View which mirror our spatial video-to-map methodology. This allows students to experience how fine-scale geographic research can be conducted.

ONE

An Introduction to Thinking Spatially About Disasters

Disasters are inherently spatial—both in terms of the physical processes as well as the human implications. Hurricane tracks, the location of fault lines, how tornadoes are generated—these are patterns or processes that have or leave spatial footprints. Where people live in relation to potential hazards or the societal impact left after a disaster can again be described in terms of spatial patterns. Within these patterns are human places, cultures, and interactions. An earthquake-devastated city is not just a landscape of damage, morbidity, and mortality but it also comprises lost (and recovering) neighborhoods, disrupted social networks, variations in resiliency, and social and environmental (in)justice. As geographers we have the technologies and spatial skills to map, predict, and ultimately understand these landscapes. This will be a common theme throughout the book: irrespective of chapter topic, geography and geographic methods play an important role.

1: CAPTURING THE GEOGRAPHY IN PAST DISASTERS

Spatial aspects of a disaster can be portrayed in terms of physical process or human consequence. The physical processes can often be described geographically in their formation (where the weather fronts meet, or the path of the hurricane), or at least their impact points can be mapped (a tornado touchdown, the earthquake's epicentre). Figure 1:1 shows an inset from a report published after the 1906 San Francisco earthquake. The map itself displays "Distribution of Earth Movement on April 18, 1906."

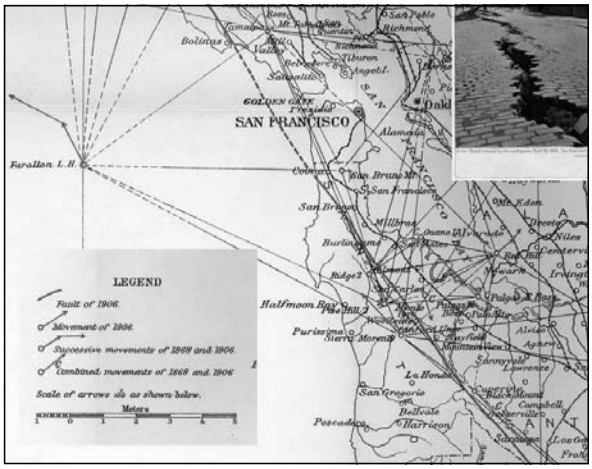


Figure 1:1. Source: Earthquake Investigation Commission. A. Hoen & Co., Baltimore: Carnegie Institution of Washington, 1908.

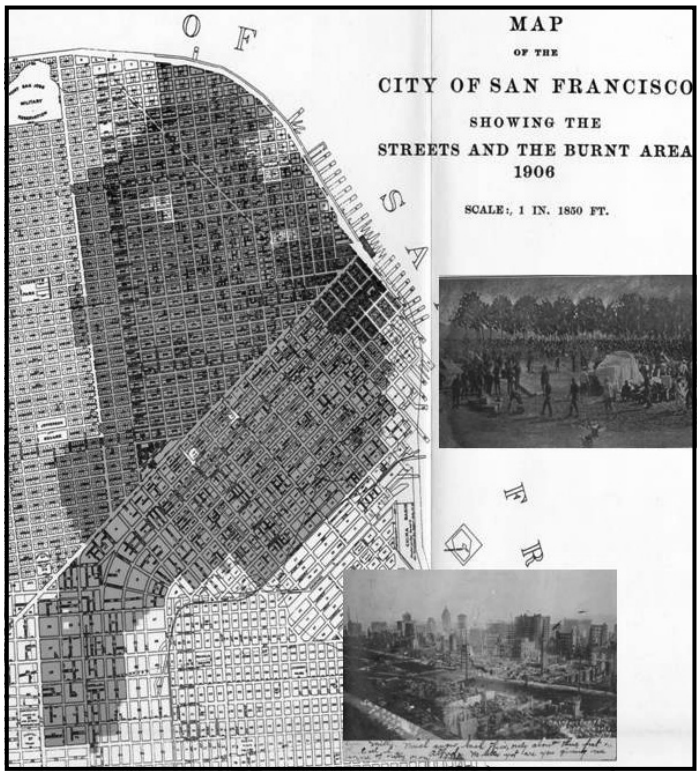


Figure 1:2.
Source: Earthquake Investigation Commission. A. Hoen & Co., Baltimore: Carnegie Institution of Washington, 1908.

Although this image provides an interesting spatial description of the physical expression of the earthquake—where the known (at the time) fault lines are and the amount of earth movement, it doesn't capture the human impact. The same report included two further maps showing sections of the built environment that succumbed to the earthquake-related fire. Figure 1:2 displays the area of San Francisco that burned[1]. However, even these maps don't capture the human emotion and suffering associated with the burn areas. This human dimension is hinted at in the inset "disaster" postcards often produced after such events. One shows a relief camp with the flames in the background, while the other has been "used" by a witness who describes how the earthquake affected her.

Another difference between Figures 1:1 and 1:2 is the spatial scale involved, an issue that will be discussed in more detail later in this chapter. Using geographic terminology, Figure 1:2 is a larger (or finer) scale map than Figure 1:1. Arguably, we have to zoom in even further, to the scale of neighbourhoods, streets, and even individual buildings, to begin to understand how all the other complexities of a disaster interact to affect people.

Alternatively, in Figure 1:3 we zoom out to a small scale (large area) map of Bengal. As an illustration of a non-US disaster, and in keeping with the historic cartography showing primary and secondary impacts presented in the first two

1 The detail in this map is good enough that it could be combined with other spatial data, such as current information about San Francisco within a Geographic Information System. This affords researchers the possibility of "recreating" some of the spatial aspects of the disaster or visualizing the destruction that could occur if the same event happened today.

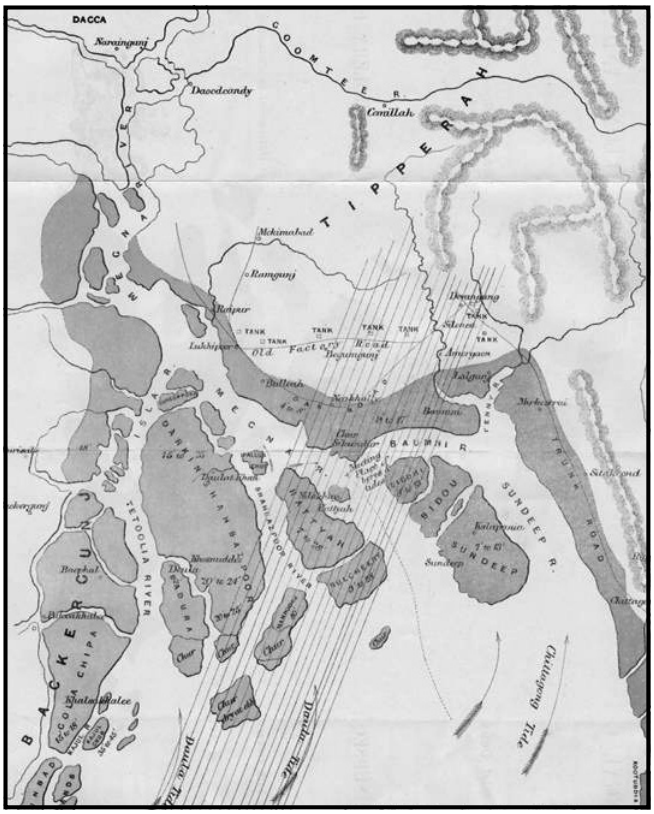


Figure 1:3. *A map from an 1877 report to both Houses of Parliament on the "Bengal Cyclone and Storm wave of the 21st October–1st November 1876; and the subsequent cholera epidemic."*

illustrations, Figure 1:3 displays the impact of a cyclone (the same as a hurricane) that struck Bengal in 1876. This map displays the geographic output of the physical event—the "*Depth of Inundation*" measured in feet, and the track of the "*vortex measured by parallel lines*." However, the death toll for this event far exceeds that of Katrina or any other hurricane in US history[2]. Although the only example of cartography in the report displays the physical process—the spatial pattern of cholera deaths could also have been mapped as well (and frequently were in contemporary reports)[3].

Q: Have you seen a newspaper or other popular media map describing a disaster that has combined both physical and human impacts?

Aside from this one example, this book will exclusively concentrate on the United States for reasons of controlling both social and geographic space in order to make the comparisons more valid. However, the reader should be fully aware that in any year there are many disasters with severe human consequences scattered

2 The report concludes: "... it is distressing to see that the ravages of cholera, following close upon the track of the first-named disaster, have carried off no less than 75,000 lives. I gather from the present papers that the total mortality occasioned by the cyclone wave and the ensuing cholera amounted at the end of last March to about 165,000 ..."

3 Cholera is (usually) spread by people drinking or washing food in water polluted by fecal matter. It was known even at this time (1877) that boiling water helped lessen the chance of contracting disease—but the upheavals, forced migrations, and general stresses found in the wake of a natural disaster often provide the perfect environment for epidemics.

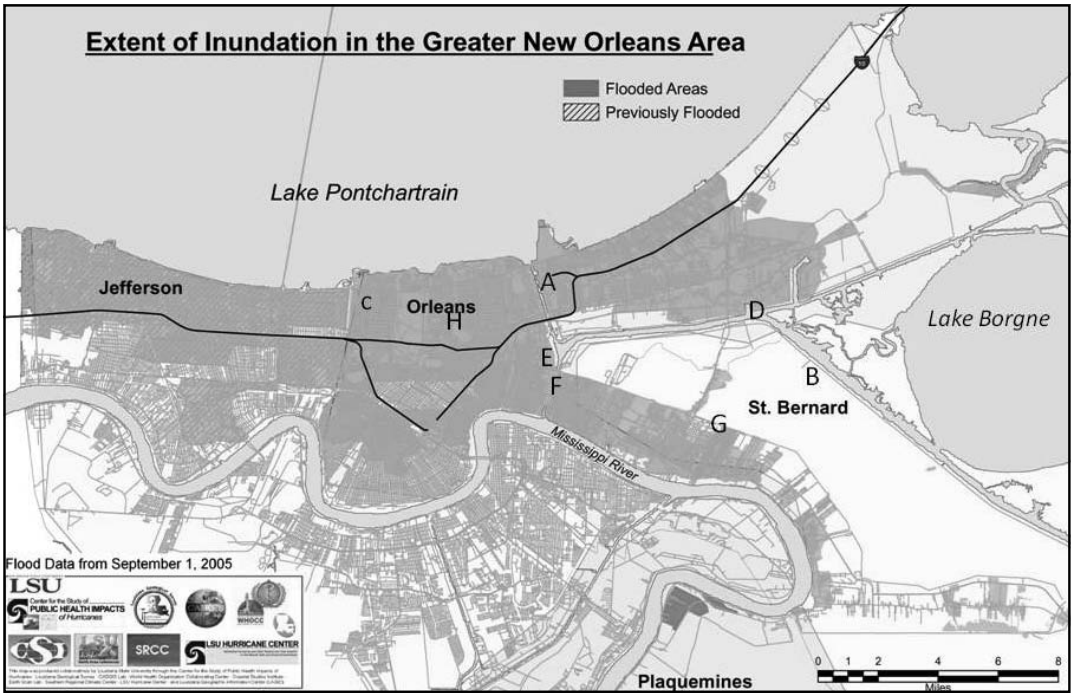


Figure 1:4. *Shows a map created in the Louisiana State Emergency Operations Center (EOC) during the response to Katrina. A further layer of letters corresponds to the sequence of events following the approach of the hurricane to the rupturing of the levee walls. The flood sequence presented below the map comes from the excellent "The Times Picayune Flash Flood" animation still accessible at http://www.nola.com/katrina/graphics/flashflood.swf. Readers are strongly advised to see this resource.* Source: Map created in the Louisiana State EOC. Specific author is unknown, but all groups who contributed data, skills or technology to this map are cited in the bottom left. Letters correspond to flood information taken from the "The Times Picayune Flash Flood."

across the globe, a great deal of which far exceed the human loss of life experienced in U.S. disasters such as Katrina[4].

These first few maps help us understand the size, process, impacted area, and consequences of the disaster. If these disasters had happened today (such as with Katrina), modern mapping technologies would have eased the collection of spatial data and made map making and information dissemination almost real time.

As many of the examples used throughout this book will involve Katrina, it is useful to briefly describe *spatially* what happened.

4 Katrina will mostly be used in this book instead of "Hurricane Katrina" and "Hurricane Rita" to capture all of the actions (including human agency) and the ongoing consequences of this disaster.

A. 4:30am—Leaking along the Industrial Canal
B. 5:00am—The levee protecting St Bernard Parish from Lake Borgne begins to fail
C. 6:30am—Water begins to leak through the 17th Street Canal into the neighbourhood of Lake View
D. 6:30am—The funnelling of water in the Intercoastal waterway breaches defences and floods East New Orleans
E. 7:30am—Upper 9th Ward, Bywater, and Treme are flooded by a Western break in the Industrial canal levee.
F. 7:45am—The Eastern levee of the Industrial Canal breaks flooding the Lower 9th Ward and beyond.
G. 8:30am—St Bernard Parish's flood defences fail from the Lake Borgne waters
H. 9:30am—The Eastern levee of the London Avenue Canal fails
I. (at location C)
9:45am—The 17th Street Canal level fails.

At this point Katrina makes land fall at Slidell on the other side of Lake Pontchartrain from New Orleans.

J. (at location H)
10:30am—The western levee of the London Avenue Canal fails

This spatial sequence of events underlies much of the description to come. As you go through the different book sections you may find it useful to refer back to this map.

2: SPATIAL CONCEPTS AND DISASTERS

The events of Katrina (just as with the San Francisco earthquake of 1906) can be described *spatially* in several ways—in terms of the physical impact, the strength, and direction of the winds, or the spatial extent of flooding. This last physical expression can be further subdivided into maximum height or temporal duration of flooding (how many days was a neighbourhood under water). Onto these physical expressions can be laid (or overlaid if we start to think in terms of different geographic layers) the amount of building damage (either measured by percentage of damage, or even a dollar amount), the location of 911 calls, or where the dead were found. There are several other variables that could be used, and some of these will be discussed throughout the book, but for now we can start to think of how these all fit together. It would seem to make sense that the strength of winds, along with flood height, might correspond with damage estimates, or even loss of life. One way to start such an investigation would be to map each layer—a common

technique used by geographers and one which will be used throughout this book. In order to do this, a Geographic Information System (GIS) is needed.

The utility of a GIS is now appreciated in many disciplines other than geography; for example anthropologists, biologists, environmental scientists, historians, psychologists, and sociologists all understand that spatial patterns and processes are important. It is an especially important tool for disaster scientists because as we just mentioned, natural disasters are spatial—and as a result the emergency management cycle is also comprised of different geographic layers. This cycle consists of four interrelated and overlapping areas: planning/ preparedness, mitigation, response, and recovery. In other words, how society intersects with our scientific understanding of hazards. As this book's primary focus is on the human geography of disasters, aspects from each of these four stages will be presented throughout the book—again with emphasis placed on how geography matters. The next chapter will describe aspects of a GIS in more detail, but first we still need to introduce a few basic concepts of both the software and spatial thinking in general. Although two chapters cannot hope to match the many introductory GIS texts available[5], they will be enough to present an overview of the importance of the system to understanding human consequence in disaster science. For example, different geographic / GIS terms have already been mentioned in this chapter, such as spatial scale and spatial patterns, and these will be discussed in the context of disaster response and recovery.

For the lay person, a GIS has many similarities to Google Earth (GE) as it allows someone to work with different maps at different geographic scales. What makes a GIS more important as a tool for disaster researchers is the level of interactivity it offers. To use an analogy, imagine the difference between a low-end digital camera and a professional use Single Lens Reflex (SLR)—both can take pictures, however the special features of the SLR, such as an increased picture resolution, make it preferable to the professional. This is not being critical of the small digital camera because it serves a purpose well, and the pictures can be shared and enjoyed. Even the professional photographer may keep one in his pocket for certain situations where the need is for a quick response. Hopefully the reader will begin to understand this analogy further as we move through the chapters.

Perhaps the best way to introduce both spatial concepts and GIS is to work through a conceptual overview of a problem. In this case we will investigate how spatial data and GIS can be used to prepare for an earthquake in Los Angeles.

5 Although there are many introductory GIS books, as well as more specialist texts, one of the best to combine both the theory and application of GIS in a easy to digest format is Longley P, Goodchild MF, and D Rhind, (2005) *Geographic Information Systems and Science*, Wiley.

Imagine a pediatric hospital in downtown Los Angeles that wants to take a proactive stance in terms of earthquake response; particularly, they want an estimate of how many pediatric patients to expect in the first several days after a large earthquake. This influx of patients is termed a "surge." What spatial information can be used to guide officials preparing adequate numbers of supplies to meet their immediate post-disaster needs and how can this information be easily communicated to improve decision making in the planning process? Planning for this surge is essential for a successful response because children require smaller sizes of equipment and different types/ doses of medicines than adults. Therefore, for a hospital to effectively respond during the disaster means they must have the requisite medical supplies to serve this population until outside support arrives. As you read through this scenario, think about the concepts that are introduced in this particular case as they might apply to other pre-disaster planning needs.

There is a 72-hour rule that follows a disaster. This means that any community, irrespective of size should be able to fend for itself for approximately three days until help arrives. First, by definition a disaster will overwhelm local resources to the point that individuals and institutions should be prepared to support themselves for several days. Second, any response effort that is immediate will take some time to reach all areas where it is needed, especially in large urban environments. Finally, the Federal Emergency Management Agency (FEMA) is not tasked with response, so their assistance is also not immediate. This reality argues that individuals and organizations should have actionable plans to deal with disaster events. Though these plans can be for protection of internal personnel, such as through evacuation plans, phone trees, meeting points, etc., the focus of this scenario is on planning to serve the surrounding community. Specifically, we will use commonly available sources of population data to show how a post-earthquake surge of one vulnerable population sector, pediatric patients, can be calculated for a hospital. However, the issues raised in this case are transferable to other groups who serve the public.

What are some of the issues that need to be considered? Part of being prepared is having accurate estimates of surge potential (how many people will be needing services in the hours and days after an event). However, having these data are not useful unless they can be shared with those who will be involved in providing services. Data must be disseminated in a format that is easy to use and in a way that gives context that has meaning for the user. After all, for emergency responders, what good is a map of locations of nursing homes if it sits in a planning document that is collecting dust on a bookshelf? What good is this map if it is outdated and does not present any information on the number of people the home serves? What good is it if it is digital, perhaps as a layer in a GIS, but either no one has GIS software or they don't have the trained personnel to use it? Clearly, the answer to all of these questions is "not very useful." However, if data are regularly updated,

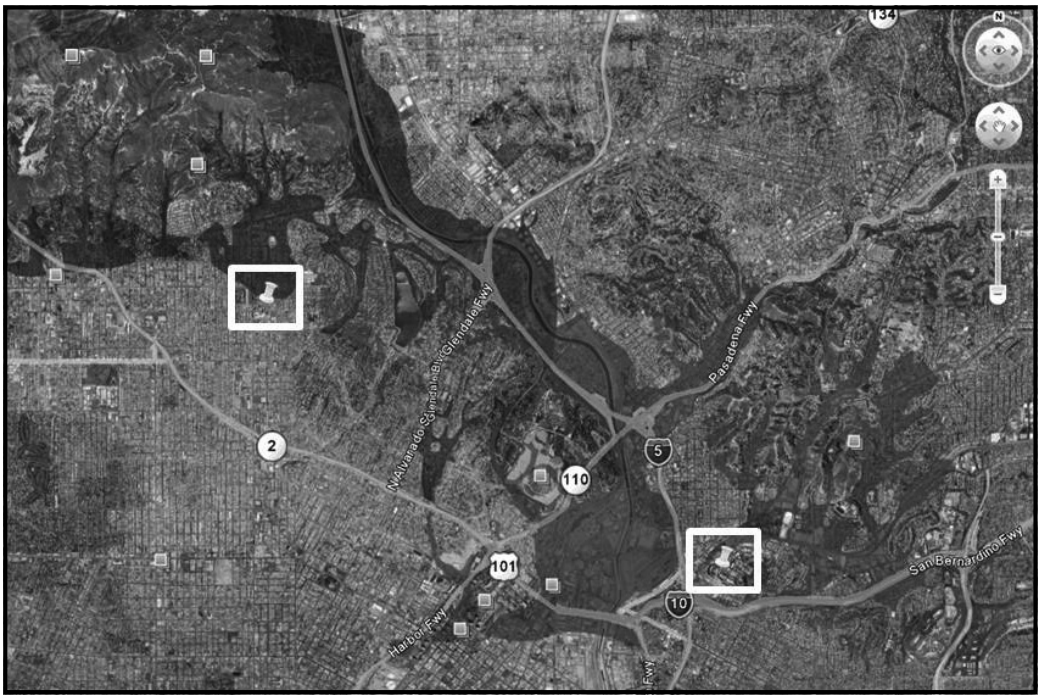


Figure 1:5. *Two hospitals are located by pins (and emphasized by boxes). These could have been located in Google Earth by using their addresses, their coordinates or even by zooming into the aerial photography. In actuality these locations were created in a GIS, as was a mask that sits on top of the map showing potential landslide and liquefaction areas.*

and are in an accessible format that can be given context (with layers such as roads, current amount of damage surrounding these places), then they have the potential to be extremely useful in planning and in response.

In general terms we need to understand basic surge potential—which means, how many patients are we likely to see coming through the doors after the earthquake? By knowing this figure we can assess where shortfalls in terms of staffing, equipment, and beds might occur. So how do we do this simple task? First, we need to know where the hospital is located. In general, this can be mapped into a GIS in one of three ways. If we know the hospital address we can match it to a street layer (we often call each individual slice of geography a layer) in much the same way Internet mapping software works. If we know the coordinate of the hospital, (maybe someone has recorded it on a Global Positioning System), then this can also be mapped. Finally, if we have high resolution aerial photography of the downtown Los Angeles area we can "heads-up digitize" the building which simply means dropping a pin or marker on the building location by clicking the mouse. All three of these tasks can also be done easily in GE.

There are several spatial concepts/issues that need to be addressed if we are to fully understand how a GIS can be used to solve a problem such as this. The first of these is the way objects interact over space (where space means a geographic area).

In this case, "objects" are people and hospitals. In effect, we need to understand how people will interact over space, how will they behave, and where will they go in relation to their hospital options? To gain this understanding, we need to consider a common geographic concept called distance decay. Distance decay suggests that the further away something is, the less importance it has, and conversely, the closer something is the more importance it has. By changing the word "importance" to "interaction," "shopping," "following a football team" or in our example *going to a hospital*, this relationship is easier to understand. All things being equal, you will go to, shop at, and support the closest team to where you live. The likelihood of you going to, shopping at, or supporting an alternative team will decrease the further away that option is. Although there are exceptions, in general the relationship works pretty well.

Q: What "exceptions" can you think of for this rule?

However, in order to maximize the accuracy of predicting how many people will come to the hospital during the earthquake, we have to think about some modifying conditions, such as, where are other "competitors" (other clinics), how large is the hospital, what is its specialty, and also, has the person been there before? Now our scenario is beginning to become a little more complicated. The size of the hospital is also important because, the bigger something is, the more likely a person is to go to it even if it is a little further away (because of more equipment, more recent techniques, and better expertise in general). This interplay between size and separating distance is common to many geographic models, and generally, if you divide the size of a place (for example the number of beds) by how far away it is[6], we end up with a "potential" value. Using this simplest of calculations, we could estimate where every earthquake victim will head for emergency care.

The second of our key spatial issues involves the way we work with data at different spatial aggregations. We can't perform the potential calculation for everybody so we have to use "spatially aggregated data"—which simply means summing all the people within a given area. It would make sense to have this aggregation by neighborhood[7], but we don't usually know the boundary of these, so instead we

6 We usually square this value as the effect of distance decay decreases at a quicker rate than just a linear relationship

7 The Los Angeles Times has a neighborhood boundary project that allows the public to view neighborhood areas in GE as well as comment on their correct spatial definition. See http://projects.latimes.com/mapping-la/api/neighborhoods/

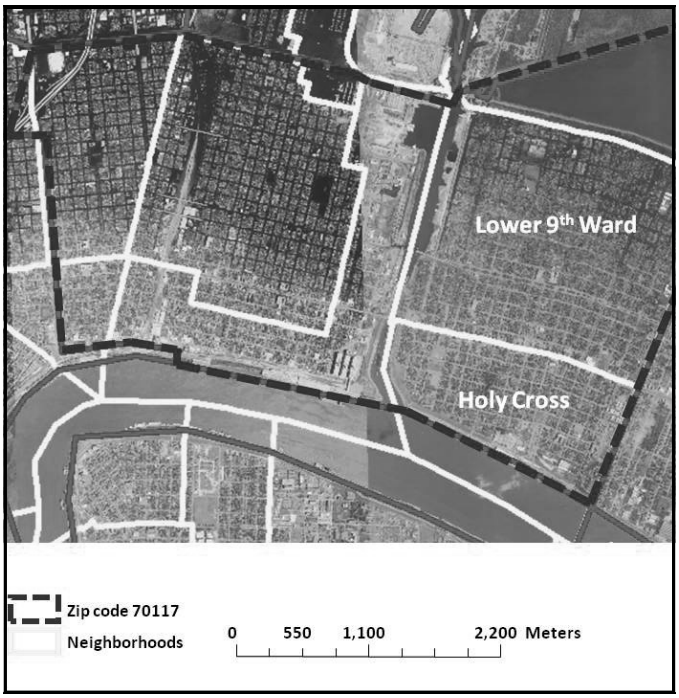


Figure 1:6. Source: Neighborhood Boundary files from the Greater New Orleans Community Data Center. Map created using Arc Map 9.3 (ESRI) as are all others in this book.

use zip codes (which is not a very useful aggregation unit[8]) or areas defined by the census, the most common being census block, block group, and tract. One of the problems with any aggregated area, but especially for large units such as a zip code, is that this doesn't match "neighborhoods" which are more representative of the processes affecting the people who live inside them. In addition, political (or postal) boundaries artificially break space and in so doing may not accurately reflect the true social (people living either side of a street) or physical (flood depth after a levee breach) landscape. Figure 1:6 shows neighborhoods of New Orleans falling inside zip code 70117. Social data made available at the zip code level, such as pre-existing health vulnerabilities, would not capture the specific living conditions or cultural landscape of the Lower 9th Ward. Similarly, any aggregate flood variable for this zip code would smooth out the high water levels found close to the levee breaks, and the relatively shallow flooding found close to the Mississippi River (seen curving at the bottom of the figure).

A further benefit of working with the census is that we can manipulate this aggregated population in different ways—we can make a map of total population, by racial subgroup, by economic status, and importantly for a pediatric hospital, by the number of children. Why is this manipulation useful? In a later chapter, we will

8 Apart from a zip code being too large and therefore encompassing too many neighborhoods, another problem is that the area is defined by postal delivery routes. It is therefore possible to have an address with a zip code number that does not sit within the zip code boundary, but rather "spurs" out along a road convenient to the postal substation. This has important implications if socioeconomic data are attached to the address by census boundaries overlaying the general zip code area. For a more detailed explanation see Grubesic, Tony H & Matisziw Timothy C On the use of ZIP codes and ZIP code tabulation areas (ZCTAs) for the spatial analysis of epidemiological data *International Journal of Health Geographics* **5**:58 (2006)

discuss the importance of "social vulnerability" which means that certain groups of society are going to be at greater risk (and therefore will require extra help) because of where they live and their general inability to cope with a massive shock[9].

A third key concept related to the issue of spatial aggregation, is that of geographic scale.

Geographic scale means how much is reality modified in order for a spatial representation (a map) to be made. There is no point in making a 1 to 1 map so we have to "scale it down" so that 1 mile becomes 1 inch, or 1 km becomes 1 cm. The more we increase the proportion between our measure of reality and the measure we use on our map, the greater the geographic area that is mapped on the same size piece of paper. A 1:100 map will contain more geographic detail, but a smaller area than a 1:1000 scale map. For extensive geographic areas, we use the phrase "small scale" mapping. For small geographic areas, such as a city block, we use the phase, "large scale" mapping. Unfortunately, large scale is used in the opposite way for many other disciplines, so here we will use "fine scale" for maps of streets, city blocks or even individual buildings. For Figure 1:7 we return to the volume of maps created after the 1906 earthquake, but this time at a fine scale showing individually impacted buildings of Santa Rosa, California.

Figure 1:7 Source: Map of the city of Santa Rosa, Sonoma County, California showing the portions destroyed by the earthquake of April 18, 1906 and by the fire consequent thereto. Earthquake Investigation Commission. A. Hoen & Co., Baltimore: Carnegie Institution of Washington, 1908. The map displays actual buildings destroyed by either the earthquake or subsequent fire.

9 Although we will return to this concept later, readers are pointed to Cutter, Susan L., B. Boruff, and W.L. Shirley. 2003. "Social Vulnerability to Environmental Hazards." *Social Science Quarterly* 84:242–261.

Q: Why would a map at this scale be useful for researchers?

Now that we have introduced some basic spatial concepts that can be applied to how we obtain and manipulate geographic information, let's turn to an equally important issue of how this information is communicated. Using the example of predicting post-earthquake pediatric surge for a Los Angeles hospital, we have identified the hospital on a map, selected aggregated population data on the number of potential pediatric patients, and now we need to consider the ways we can share this information with decision-makers. After this next section we will return to the Los Angeles example and work through it in detail using the spatial concepts introduced in the chapter.

3: COMMUNICATING SPATIAL INFORMATION

Communication takes many forms for people affected by a disaster. It can be the lack of a means to communicate with others, such as friends and family. It can also be the lack of a reliable information source. Here are two "communication" tales with regards to evacuees from New Orleans. One colleague went into a shelter close to Natchitoches, Louisiana, taking two lap tops so that the people there could use the Internet to search for information. This shelter, as with many others, had no provision to relay current information. Most studies on the psychological impacts suffered during a disaster will comment that uncertainty, which can lead to "dread risk"—the negative exaggeration of any event, is at least in part caused by not knowing what is happening, and what may come. There is therefore a medical justification as well as a humanitarian imperative to inform survivors about what has happened or is happening. The second anecdote involves a couple in Morehead, Kentucky at the end of 2005. We were giving a talk about the response effort when afterwards we were approached by a couple who told me that they had originally come from St Bernard Parish—one of the hardest hit areas to the east of New Orleans. They told me how they had received phone calls from friends in their old town during the days following the storm emergency 911 calls that could not be placed to the Louisiana based EOC because the local circuits were either down or overloaded. They literally had to call Kentucky, and have their messages relayed back to Louisiana. On one hand it shows how we now live in such a small geographic space, and on the other hand, how important it is to understand the fragility of our traditional means of communication.

What is interesting is that U.S. disasters after Katrina have begun to use spatial approaches to communicate. After the California wildfires of 2007, Google Earth was used to relay daily updates as to the status of the fires, which roads had been blocked, where mandatory evacuation orders were in place—even what form of ID you would need to regain entry back into your neighborhood. This information

was updated regularly by the public broadcasting station KPBS. This approach was exactly what was required for those facing the uncertainty of a disaster—even to the level of detail as to how many spaces were left in each shelter (See Figure 1:8)[10]. Google Earth has since been used in several other disaster situations, providing excellent geographic detail and a means to disseminate information quickly and easily.

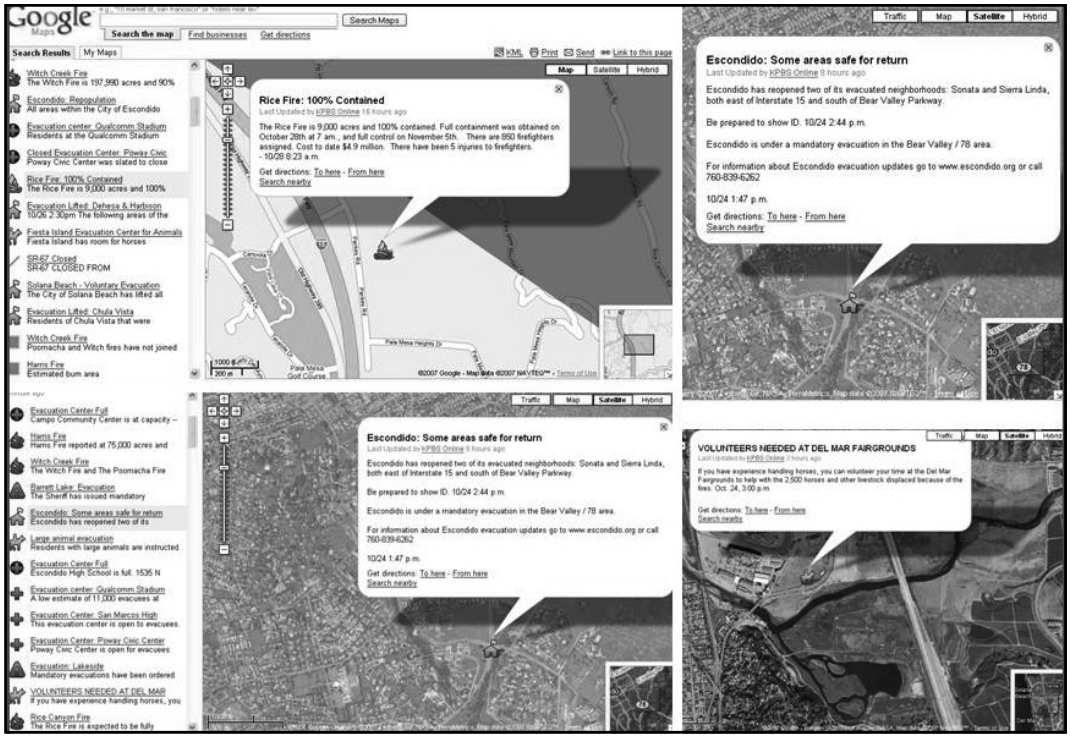


Figure 1:8. *Four snapshots from the constantly updated Google Maps page hosted by KPBS online during the San Diego wildfires of 2007. This system allowed people impacted by the fires to assess the approaching risk to their neighborhood, where shelters were located, and if they were full, and also (using standard Google Maps features) which roads were clogged. In addition, volunteers could use the system to see which goods were needed in shelters or to help animals. One nice feature was telling returnees what they would need (in terms of identification) to be allowed back into their neighborhood.*

10 Readers are pointed to the following paper Backchannels on the Front Lines: Emergent Uses of Social Media in the 2007 Southern California Wildfires by Jeannette Sutton, Leysia Palen & Irina Shklovski in the *Proceedings of the 5th International ISCRAM Conference*—Washington, DC, USA, May 2008 F. Fiedrich and B. Van de Walle, eds

Q: By using different Internet search engines—how many other Google maps/ Earth disaster sites can you find? Which of these was generated during the disaster itself as a near real time information exchange?

It should never be forgotten that a map is a communication device—just as important if not more so than the written word. The audience for the previous wildfire example was the general public, though these tools also serve major communication roles for responders. For example, during the first few days after Katrina, our World Health Organization Collaborating Center for Remote Sensing and GIS for Public Health (WHOCC) helped provide some spatial support for Red Cross damage assessment teams.

The Red Cross HQ had been set up in a large hall in Baton Rouge and the place was buzzing when we arrived. Outside in the parking lot were two high tech trucks, while larger food container rigs were also parked nearby. The area inside the hall was split into stations, many having a single computer with printer. We had been told to go to the station dealing with damage assessment. Once there we introduced ourselves and presented our first poster/map as an introductory gift. This would be an approach we would use in several other situations—presenting a useful visual aid means so much more than just "talking." The poster

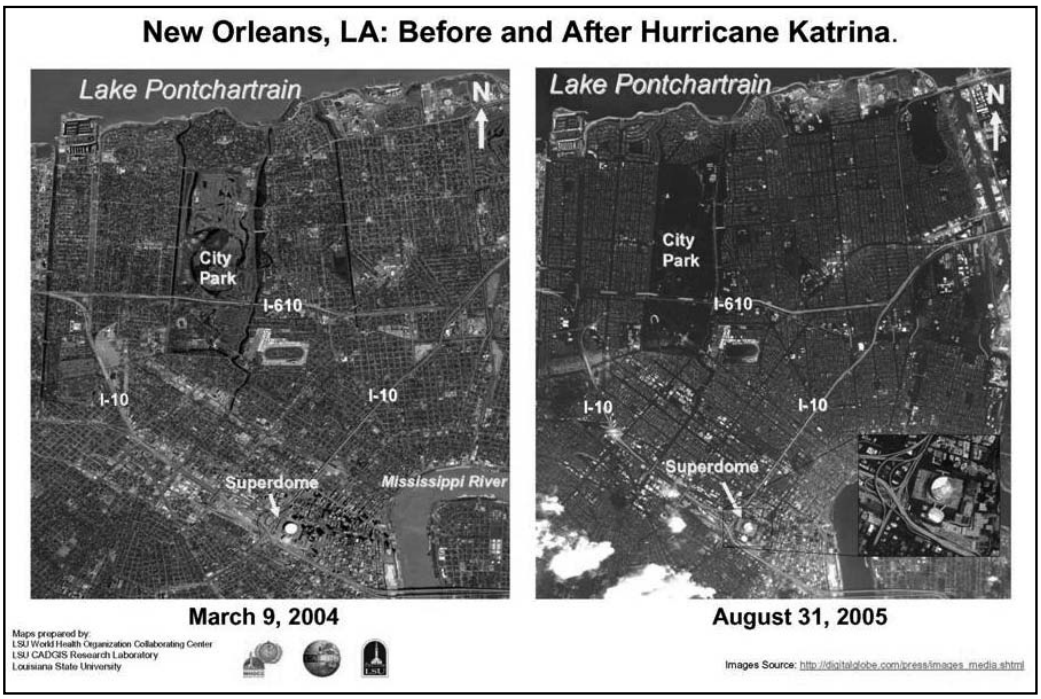


Figure 1:9. Source: Original poster created by Jason Blackburn, PhD while at the World Health Organization Collaborating Center for Remote Sensing and GIS for Public Health.

showed a before and after aerial photograph of the area around the Superdome, the flooded streets clearly visible (see Figure 1:9). One of our team members had downloaded the flood imagery and matched it with an aerial photograph from the "Atlas" geospatial warehouse housed at the CADGIS lab[11]. This immediately sparked conversation—not so much with us but between them—which is exactly the response we wanted.

Q: Figure 1:9 was created during a time of great stress and it served its purpose well. However, if you had more time, how could this poster be improved?

We were immediately asked if we could make similar poster size maps for other areas. At this point we had limited access to post hurricane imagery beyond New Orleans, but we certainly could use existing data from "Atlas." We agreed to make six posters, with underlying imagery, parish boundaries, and major roads overlaid on top. We also agreed to have them back to the group by the end of that day. These posters were to be used to help in decision making, and as a focal point for briefings/debriefings.

Q: Why do you think a poster sized map would help during disaster response briefings?

At this point it is useful to explain how Red Cross damage assessment works in a post disaster environment. This is another example where you can apply spatial thinking to a disaster-related problem. Groups of volunteers, comprised of local chapter members, as well as national volunteers flown in from all across the U.S., would go out and assess the amount of damage to residential structures. These volunteers are largely comprised of retirees as they have time and flexibility. The results of these assessments are used to determine the degree of damage to a structure so that relief payments can be metered out. The assessments are carried out in the following way, a team of two to three people drive to a previously designated neighborhood and then, without getting out of the car, they record the house number, what type of structure it is, and how much damage has occurred. These entries are recorded onto a paper sheet which is stored in a box back at the HQ. When first being told about this system I was amazed at how low-tech it was…I've often made the comment in presentations that I can only imagine that there is a warehouse somewhere, similar to the scene at the end of *Raiders of the Lost Ark*, where all these boxes of assessment sheets are stored. All this wonderful information is not

11 Readers can go to www.atlas.lsu.edu where they can download the same imagery, along with a host of other useful geospatial data, much of which was used during the response to Katrina.

only being fully utilized during the event itself but it also runs the risk of being permanently lost because no digital copy is made. Imagine how useful damage assessment data for the Northridge earthquake would be now. Although it took us several days, we eventually managed to get a Xerox copy of the sheets and geocoded[12] the damage assessments. One of the challenges faced by researchers after a disaster is how to collect data that is representative of the post disaster area and its returnee population. If, for example, you want to understand the amount of stress returnees face on returning to their homes—how do you collect that data? If you use census information to guide your data collection (for example, selecting from low, middle and high income areas), then this does not take into account the post-disaster population, not does it capture the disaster "exposure" commonly meaning the amount of damage caused by the event. If you use damage maps to help guide where you want to collect data—how do you know where to start, and how to get a representative sample of people from within this area[13]? In addition, the high stress environment of a post-disaster landscape not only includes physical impediments, such as impassable roads, but also the emotional state of returnees who do not want to be "studied" making disaster research one of the most challenging environments for academics.

The geocoded Red Cross sheets could improve this spatial sampling frame by detailing on a street-by-street basis how much damage had occurred. By always being aware of preserving spatial confidentiality, and therefore not releasing actual points on a map[14], we would be able to generalize areas of the city where the damage

12 This simply means placing addresses on a map–it will be described more fully in the next introductory chapter to GIS

13 Two post Katrina surveys conducted in October of 2005 were described in the CDC's Mortality and Morbidity Weekly Report (55), both of which employed a spatial sample frame. In the first 45 census blocks were selected, with those having fewer than 20 houses excluded. Four coordinates (lat and long) were randomly generated in each census block, and the field team navigated to these with a GPS and picked the nearest residence. Problems with using this style of survey design include a reliance on pre-Katrina population data (not the returned population), and a bias towards the less damaged areas of the city "Assessment of health-related needs after Hurricanes Katrina and Rita--Orleans and Jefferson Parishes, New Orleans area, Louisiana, October 17-22, 2005." *MMWR Morb Mortal Wkly Rep* 55(2): 38-41. In the second investigation into mold risk, census blocks with more than 20 homes were again selected, but blocks were stratified by damage into mild, moderate, severe using FEMA flood and damage maps. A GIS was used to generate a proportionate number of random coordinates (lat long) within each stratum. Field teams again used a GPS to find the random coordinate, and from this selected the house nearest or north of the waypoint. Sample limitations were similar as for the first study "Health concerns associated with mold in water-damaged homes after Hurricanes Katrina and Rita--New Orleans area, Louisiana, October 2005." *MMWR Morb Mortal Wkly Rep* 55(2): 41-4.

14 The concept of spatial confidentiality is a major concern for people using health data in a GIS environment. Unfortunately normal "rules" become more lax during a disaster response and there is a real risk of making maps that can compromise an individual at a later point. For more information

Figure 1:10. *Two A4 research maps used for collecting data on mortality locations in New Orleans. Deaths are shown as points on the map, and the hand drawn arrows and notations show field notes taken as the team visited each mortality site. The top map is the Lower 9th ward (including Holy Cross), while the bottom is the area around the London Avenue canal break*[15].

had been severe, or light, in both racially different, and economically varied neighbourhoods. This approach was actually employed by one team from LSU interested in gauging returnee stress loads. In order to help their field-data collection teams this spatial sample frame was mapped onto A4 paper—we had found that this size was perfect for field-teams using clipboards, both for search and rescue teams during the response stage, and also for our own research in New Orleans (see Figure 1:10). If we had to do this again, we would have created a GE mash-up and allowed them to spatially interact with the maps through any internet access point, even in the field if they possessed suitable mobile technology. As previously mentioned, GE is a great tool to disseminate spatial information—combining maps, images, and GIS overlays to help understand the geography of a place.

see Curtis, A., Mills, J.W., and M. Leitner (2006), Re-engineering confidential information from maps about Hurricane Katrina, *International Journal of Health Geographics* 5:44

15 Although readers might think these locations are revealing confidential information, they are actually best estimates extracted from a local newspaper.

This initial interaction with Red Cross damage assessment would lead to our adoption of a new means of spatial data collection utilized throughout this book. We were giving another presentation in Maynooth, Ireland, at the National Center for Geocomputation and one of the other presenters discussed a system whereby a digital camera (or two or three) could be synched to a GPS device for the recording of motorway conditions. This type of approach could be used to check the road surface, the state of road signs, or even the encroachment of vegetation. I immediately saw the potential for Red Cross disaster assessment. Imagine a car with two cameras, attached to either side of the vehicle, recording building damage as we drove. Instead of stopping and manually recording an address, a type of structure, and the amount of damage—all this information could be recorded on video, and synched to the right coordinate. Back at the HQ, a team working through the night could then process the video, in effect completing onscreen damage assessment sheets through a pop up window on the video output. With a little additional programming an address could also be estimated to the GPS coordinate. The benefit of the system was obvious; it would be exponentially faster and require far fewer volunteers, thus reducing the Red Cross's budget (volunteers need to be housed and fed). In addition data could be quality checked for accuracy at any point, something which obviously couldn't happen with the paper copies. Data are also recorded digitally, allowing for archiving, and distribution between multiple EOCs. Finally data could be used for other disaster research, such as HAZUS (FEMA's damage estimation program) validation.

By the end of February 2006, we had established a working relationship with the National Centre for Geocomputation (NCG), and through their generosity a single camera unit had been shipped over from Ireland. A group of us took the unit, suctioned cupped the digital video camera to the side of our car, and headed off to New Orleans. The GPS unit itself was small, no larger than a laptop battery, in fact the whole unit was extremely portable, easily fitting into a single hard-shelled case—again meaning it would be easily transportable with the Red Cross teams. We decided to shoot three one-hour films, one to cover the whole of City Park—the issue at the time was whether sections of the park should be used for FEMA trailers—and then cover as much as possible of the Lower 9th Ward.

To some degree this was complete guesswork, we had no idea how effective the GPS was, or even if it was working (there was no LCD screen—just a box with small green and red lights), we had no idea what was the right speed for either the best video image, or GPS recording, nor how the overcast day would affect GPS reception. The whole package, tapes, camera, and GPS unit, were then shipped back to Ireland. When we received the DVD's of the trip back, and after many attempts to correctly configure the browser system, we were stunned. To the left hand side of the screen, the entire pathway through the Lower 9th Ward was displayed. A red

Figure 1:11. *Spatial video collected using NCG equipment in the Lower 9th ward on 3/11/06.*

arrow indicated the direction of travel (see Figure 1:11). As we started the video, so the arrow would slowly move along the path. On the main screen, the video image was displayed. Although the video was a little blurry at times, possibly as a result of the driving speed, the amount of damage to each structure was easily visible. If Red Cross had used this data collection approach, the volunteer could have easily recorded data into a database approximating the current hard-copy collection form used by Red Cross.

The three snapshots show the same section of road close to one of the Industrial Canal's levee breaks. In the first image, the flood imagery to the left of the browser shows the water pouring through, and the barge that is thought to have punched a hole in the wall. In the accompanying spatial video

image, the barge is indicated by a box. The middle image progresses along the same stretch of road. This time the flood imagery has been zoomed into so the house accompanying the spatial video image can be matched to the "map." This image shows severe damage, the house having collapsed, with the roof now on the ground. Search and rescue markings are also visible on the building. The third image adds the current *Make it Right* (MIR) building project area which corresponds to Figure 1:11. The spatial video image shows a temporary relief shelter set up for returnees.

The browser could also display multiple other cameras, though for this proof of concept we had just used one, and this meant every road had to be driven twice. A damage assessment team would affix one camera on either side of the vehicle, thus cutting the travel time in half. As a result, because of this Lower 9th Ward data run, we now have a spatial snapshot in time of what the neighborhood looked like after Katrina. The area now has totally changed; in one corner the Make it Right Foundation has begun a new home development, scattered other rebuilds can be

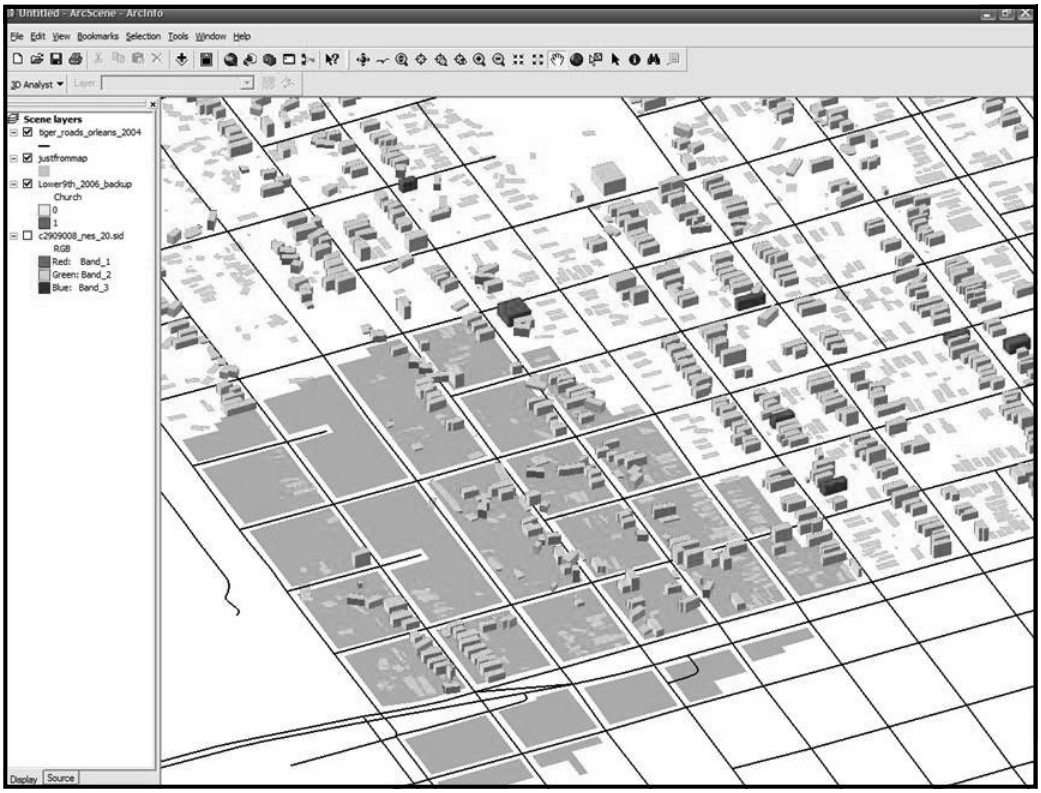


Figure 1:12. *A typical GIS window where the information from spatial video in Figure 1:11 has been extracted and turned into a 3-D map. The shaded area is the current MIR rebuilding project area.*

found between the abandoned homes and massive vegetation overgrowth. Most of the homes have been bulldozed. If you think back to the first few maps of this chapter, maps that displayed different aspects of major disasters from the past. This digital spatial surface is our modern equivalent, only now future researchers will have a video record, and because it is spatially referenced they will be able to manipulate it, analyze it, and map it in different ways[16].

Now that we have covered some of the basic concepts and approaches to thinking spatially about disasters, let's work through a real-world case that requires use of these concepts and also consideration of greater spatial complexity in the problem-solving process.

THINKING SPATIALLY ABOUT DISASTERS: AN APPLICATION

We previously identified a disaster related spatial problem—estimating the likely surge after an earthquake in Los Angeles. We also introduced a few basic spatial concepts necessary to understand and approach a solution, including distance decay, spatial aggregation, and spatial scale. We will now return to this case to apply some of the concepts we have introduced in this chapter. Four basic steps can be used to develop an accessible, all-hazards geographic resource for use in planning post-disaster surge. Step One: Identify a service area. Step Two: Identify the service population. Step Three: Improve data where possible then repeat Step Two. Step Four: Disseminate the data for use by decision makers. Notice the generality of these steps. There is no mention of a specific type of service, a specific type of population, nor of a specific type of event. Let's think through the following steps.

Step One: Identify the service area

What services need to operate in a disaster? The answer to this question ranges from local entities, such as fire departments, police, and hospitals, to state and federal agencies among others. These resources are part of a place's critical infrastructure. Knowing where these assets are located and the capacity that they provide is essential to planning and response functions. However, these data are often stored in tabular format, which does not provide a geographic context for their use.

Furthermore, to demonstrate the importance of accessibility and context, look at Figure 1:13. This image is a layer of hospital locations in Los Angeles

16 Readers should see our publication which details how three measures of damage were mapped from the Lower 9th Ward video. This publication also provides an example of a Red Cross street sheet. Curtis, A., Mills J.W., Kennedy B., Fotheringham S. and T. McCarthy (2007) Understanding the geography of post-traumatic stress: an academic justification for using a spatial video acquisition system in the response to Hurricane Katrina *Journal of Contingencies & Crisis Management* 15(4): 208–219.

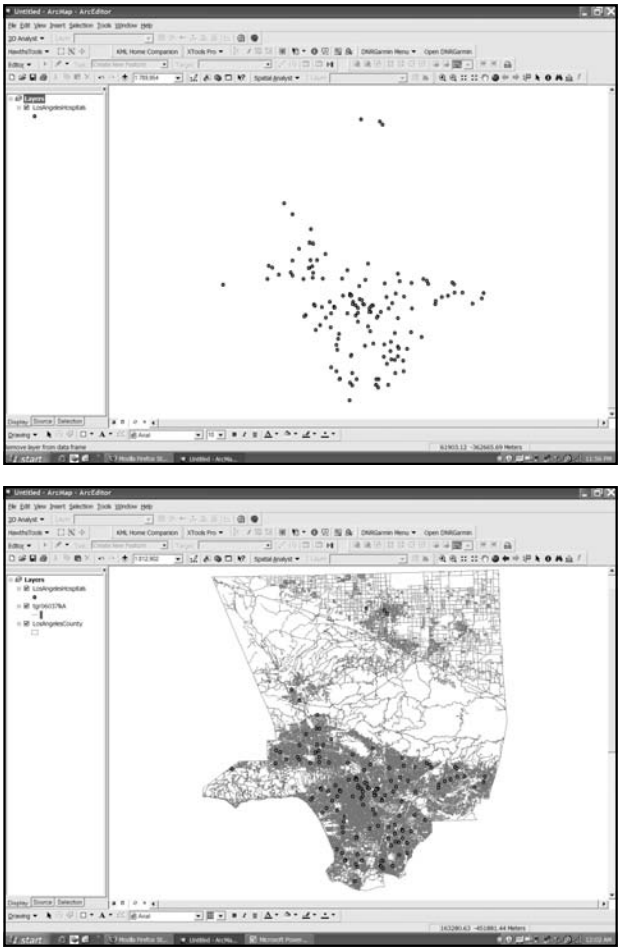


Figure 1:13. *(a) A map of hospital locations in Los Angeles County, California. The GIS layer is the only data presented in the map. (b) The same map from (a) is presented with the addition of the county boundary and roads.*

County, California. These data were extracted from a larger file of Licensed Healthcare Facilities that is publicly available from the California Spatial Information Library (CaSIL) and were originally created by the California Office of Statewide Health Planning and Development (OSHPD). Figure 1:13 (a) presents these points by themselves, while context is added with a county boundary and roads in Figure 1:13 (b).

Q: What other layers would help add context to the map?

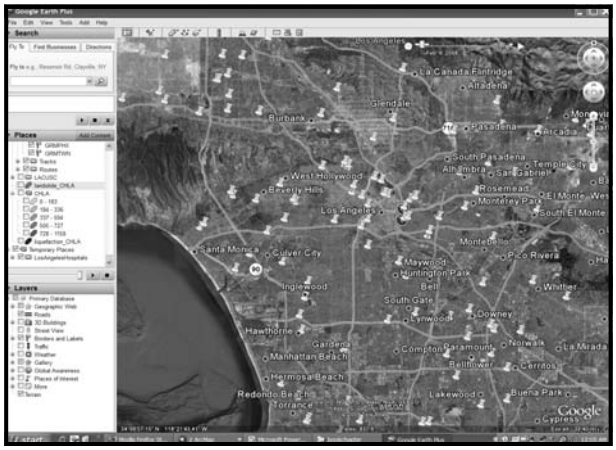
Q: What do you think planners and emergency responders need to know about the geography of these service provision locations?

However, in paper format, this is still not a useful planning tool because not all road names and hospital names can be displayed without creating a cluttered map. Alternatively, in Figure 1:14(a), this same layer of points is presented in Google Earth and in Figure 1:14 (b) we can see how much geographic context can be gained from simply zooming into each hospital, in this case the Los Angeles County + University of Southern California hospital (LAC+USC). This example demonstrates the concepts of accessibility (a paper map or GIS layer vs. Google Earth) and context (dots on a map vs. dots linked to imagery of the surrounding area). Furthermore, this demonstrates the first component of Step One, identifying locations of critical service provision.

Q: How might data presented in Google Earth be more accessible and have more context than a paper map?

Q: How might a paper map of the same data be more appropriate for planning or response?

The second component of Step One is to select the service region. This is an area surrounding the critical service provision location. For a study considering disaster related surge potential in a hospital, the simplest form of defining a service region would be to create a catchment area outwards from the facility by a reasonable distance. From the perspective of mapping, the technique used to define this region is called buffering. In essence, a shape (buffer) is drawn around the point of interest, and in this case the catchment area is defined as the space that falls within this buffer.



Q: Buffers are commonly used in environmental health and environmental justice studies to examine the impact of hazards, such as chemical releases and traffic exhaust. How would you use buffers to study the impact of a chemical release? Or the relationship between respiratory problems and the distance a person lives from heavily trafficked roads?

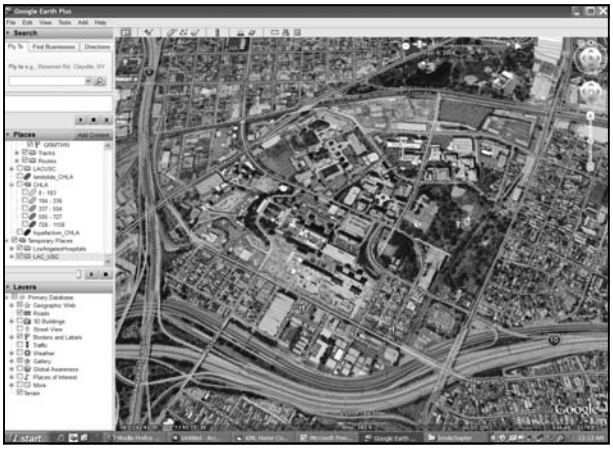


Figure 1:14. *(a) Locations of Los Angeles County hospitals. This is the same layer from Figure 1:13, but the file format has been converted so that it can be visualized in Google Earth. (b) A close-up of the area surrounding LAC+USC hospital in Google Earth.*

Buffering involves consideration of two issues: 1) buffer shape and 2) buffer size. In a GIS, buffers are commonly equidistant around a feature. However, this default approach is not necessarily appropriate for determining an area that will require specific services in a disaster. For example, using our case of post-earthquake pediatric surge at a Los Angeles hospital, we could simply generate a circular buffer at 0.5 mile, 1 mile, and 3 miles around the hospital. Though this is a reasonable method for approximating a service region, let's think about the geography underlying this selection. First, these distances (buffer sizes) could be justified by saying that they would capture population within a walkable distance to the hospital. Assuming the likelihood of damaged transportation lines (such as use of buses, local roads, highways), people would be walking (or would be carried) to reach medical services. So, in this case, the buffer size makes sense.

Q: How might buffer size vary based on the type of event (e.g., wildfire, earthquake, flood), physical geography, and urban/rural setting?

Now let's examine buffer shape. Though concentric circles around a point are commonly utilized, other shapes may be more appropriate, such as semi-concentric circles or a buffer that follows an arterial network. Concentric circles assumes an isotropic plan; that access to the center is equal in every direction. However, in reality, how often is this the case?

In a disaster, a lack of thoughtful, geographically-informed planning can have a real impact on whether or not the plan is realistic and results in a successful response. Something as simple as buffer selection can have consequences for people's lives. The stakes are this high in planning for disasters.

Step Two: Identify population in the service area

Now that we have introduced concepts of service location and the region they would likely serve in a disaster, the next step is to identify the population in this area. How many people will constitute the surge? More specifically, can we identify subgroups in this population that will need special consideration in planning disaster services? In New Orleans, after Katrina these people included the elderly, multi-generational households, people suffering from both chronic and infectious disease, the physically impaired, and the obese. Each of these issues necessitates specific plans for evacuation and medical care. However, such specificity was not utilized and therefore the most vulnerable suffered disproportionately in this disaster. What could geographic information have contributed to planning for a successful response?

Using the basic geographic technique of overlay in a GIS we can develop some simple scenarios for determining the entire population for the area, subsets of the population that display social vulnerability characteristics, and subsets of the population that live in biophysical hazard zones in addition to also being socially

vulnerable. Two publically available data sources are needed to develop such geographically specific surge plans. The first is the United States Census. The second general source involves more specific biophysical risks (the source for these may be local, state, or a federal agency providing spatial data on hazard zones). In the case of the earthquake hazard in California, we can use landslide and liquefaction zones provided by the California Geologic Survey (CGS).

The Geography of Vulnerability

Planning for disaster can take many different forms. Emergency services participate in training exercises, businesses invest in disaster contingency consulting, and families develop action plans about what to do, who to contact, and where to go. In reality, planning cannot ensure complete preparation as so many different scenarios may develop in the event. This is not to say that planning is not useful, it is and if a realistic plan is practiced enough, it will pay off when needed. Though the details of a disaster may be difficult to predict, research tells us that there are some constants that will occur and therefore plans can be developed to address them. One of these constants is the disproportionate impact on vulnerable populations. Vulnerability will be addressed in detail throughout this book, so we will not dwell on the topic here except to introduce a few key points relevant to planning with geographic information. First, vulnerability can take different forms, such as health vulnerability, social vulnerability, and biophysical. Second, regardless of type, each exhibits a geography; there are spatial patterns to the locations of hurricanes, earthquakes, health burdens, and poverty, for example. We want to identify these geographies and then use them to develop improved plans for serving the people and places impacted in a disaster.

Though biophysical vulnerability is composed of measurable factors surrounding an extreme event, which in this case includes proximity to landslide zones and liquefaction zones, social vulnerability is a more complex concept. The blend of components which create social vulnerability vary from place to place. Several studies have found that factors related to these types of vulnerability, in addition to built environment characteristics[17], are linked to earthquake injuries. For example, one study found that age and disability were factors for hospitalization after the 1994 Northridge earthquake[18].

17 Peek-Asa C, Krauss JF, Borque LB, et al. Fatal and hospitalized injuries resulting from the 1994 Northridge earthquake. *International Journal of Epidemiology* 1998; 27: 459–465; Shoaf KI, Sareen HR, et al. Injuries as a result of California earthquakes in the past decade. *Disasters 1998*; 22: 218-235; Peek-Asa C, Ramirez M, et al. Seismic, structural, and individual factors associated with earthquake related injury. *Injury Prevention 2003*; 9: 62–66; Ramirez M, Peek-Asa C. Epidemiology of traumatic injuries from earthquakes. *Epidemiologic Reviews 2005*; 27: 47–55.

18 Peek-Asa C, Ramirez MR, Shoaf K, et al. GIS mapping of earthquake-related deaths and hospital admissions from the 1994 Northridge, California, earthquake. *Annals of Epidemiology 2000*; 10: 5–13.

Data Sources

Q: How can we begin to use a GIS to understand all these different layers?

The United States Census provides data on a decennial timeframe, so they are useful as baseline or approximation only, which is a limitation. However, they are publicly available and geographically complete across the United States so that these data can be used by anyone in the U.S. and at a variety of scales: block, block group, tract, though the finer the scale of data, the better. The census has both data about people (race, income, education) and also about their environment (year residential structure built, home owners/renters).

Census data are downloadable in a tabular format, but as we have already demonstrated earlier in this chapter, tables are not at all sufficient for seeing the spatial patterns in data. However, the data in these tables can be mapped in a GIS. These benefits make it a useful dataset for planning and the limitation of temporal applicability can be overcome, which will be discussed in the next section on collecting primary data.

Figure 1:15 shows the spatial pattern of only one characteristic of social vulnerability. Many more variables exist. Therefore, to gain a more comprehensive understanding of how many people may need medical services in a post-earthquake environment, these variables should be combined. Furthermore, social vulnerability varies geographically, for example the factors that make someone vulnerable on the Gulf Coast may be different in some respects to factors in Southern California. However, this is a benefit of the Census in that data about the population (including the many social vulnerability indicators) are available throughout the country. Mapping social vulnerability, then, can be modified based on what makes sense for specific places.

Hazards Zones: The other main category of publicly available data that can be used to plan for population needs in a disaster is hazard zone data. These can come in a variety of themes and are developed by several different agencies. As a result, hazard zone data are not as consistent across the country as are Census data. For example, landslide and liquefaction zones for California are created and made available by the California Geologic Survey (CGS), while flood zones are available nationally due to their oversight by the Federal Emergency Management Agency (FEMA). Finally, some local governments collect and distribute hazards zone data for their municipality. For example, in San Diego County, California, SanGIS (www.sangis.org) provides data on locations of wildfire severity zones.

Although data on social and biophysical vulnerability are useful alone, they are even more beneficial for planning post-disaster population surge when they are combined, or layered onto each other in a GIS. Applying such a process could

show that, although an area contains several hazard zones, few people actually live anywhere near them (this may not matter in an earthquake, but perhaps would make a difference in a flood). Alternatively, the resulting map might show that high densities of socially vulnerable people live clustered in a hazard zone at the edges of a major city, such as is a common case for the poor living in landslide zones in Latin America.

Overlay

Now that you can access data on population and physical geography as they relate to a potential disaster event, we will discuss how to combine Step One with Step Two to identify populations in a specific service area that may be disproportionately impacted by a disaster due to the combination of social and biophysical vulnerability.

The most common means of displaying spatial information, such as numbers of elderly in a liquefaction zone, is in a graduated color map. The simplest form of these maps would be comprised of administrative boundaries, for example by census tract or blockgroup. A GIS allows the manipulation of these data into more appropriate geographies in relation to a hazard. For example, buffers can be used to create an area of impact around a key feature–either a hazard location, or facility expecting surge after a disaster. The population living or working in this buffer zone can be identified as "at-risk" for a specific event (earthquake) or have ongoing exposure (particulate matter).

However, a different GIS approach involves "overlaying" data, which in effect means stacking spatial information in the search for common intersections. For example, overlaying demographic information on a highway network might be used to show that higher levels of poverty spatially correlate with close proximity to highways, which in turn might be used to prove a thesis on environmental justice where impoverished cohorts suffer disproportionately from particulate matter exposure. For a study considering disaster related surge potential in a hospital, the simplest form of analysis would involve extending zones of impact (buffers) outwards from the facility, and extracting out (overlaying) the census derived vulnerability found within.

Cartographic analysis is comprised of looking at spatial layers to identify areas where they align or correlate, such as blockgroups that have high values for low educational attainment, high single parent households, and high numbers of families where English is not the first language. Perhaps some of these areas are also proximate to a hazard zone. A next step would be to perform a spatial analytic technique to test the apparent relationship. Then, if this area is identified as a hot spot of multiple vulnerability characteristics, it should be prioritized for updated pediatric population counts as children in these places are more likely at risk.

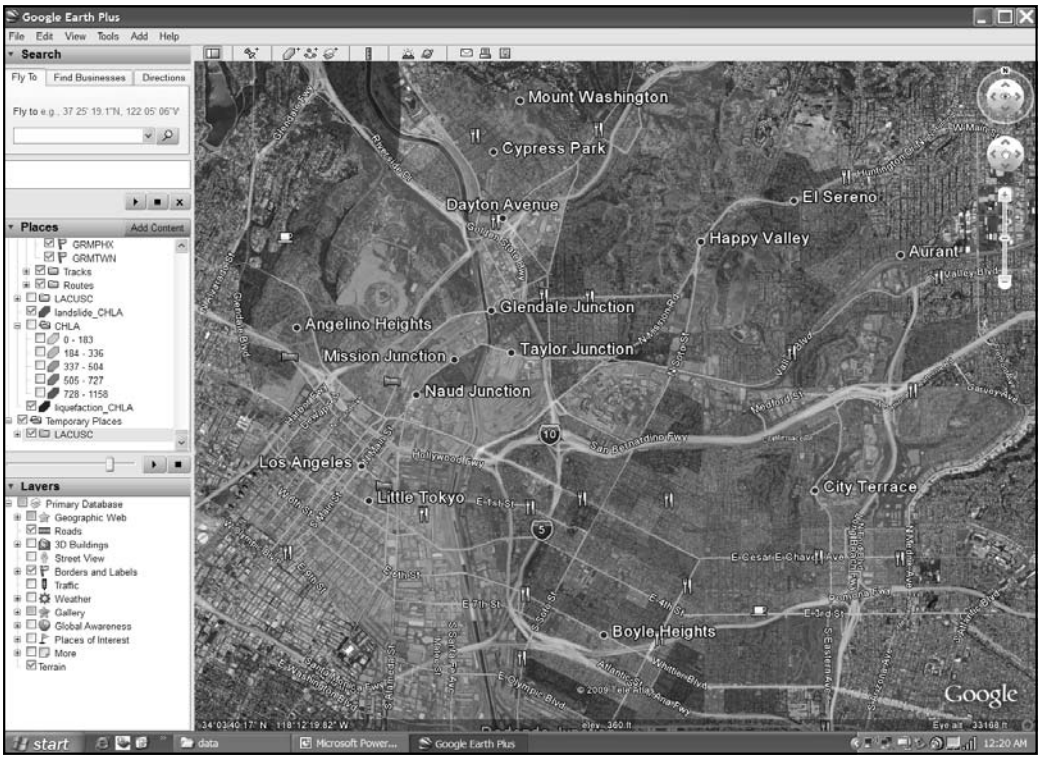


Figure 1:16. *Putting it all together: Overlaying data on service provider (hospital), immediate post-disaster service region (buffer), biophysical hazard zones (landslide and liquefaction), and a social vulnerability characteristic (median household income).*

Step Three: Improve Data, then Repeat Step Two

The basic surge prediction approach employed in this section provides a quick glance at the number of people and the types of needs that will be faced in the early days after a disaster. Therefore, this method is a suitable first step to help organizations plan their response. However, there is room for greater specificity and the approach can be dramatically improved to gain a more accurate understanding of the population needing help after a disaster. This improvement can be made in a couple of areas, such as refining the buffer (which we have already discussed), but also through considering issues of distance decay and competing destinations.

A major improvement for planning post-disaster surge predictions could be made through collecting primary data, such as more accurate information from the vulnerable population falling inside the buffer zones. A simple survey could be targeted to people located inside the service region to ascertain answers to simple questions such as, *where would you go in the event of a disaster*? Alternatively, a

survey can be conducted of the neighborhood built environment to capture both physical and social characteristics.

Step Four: Disseminate the data for use by decision makers

GIS software is now relatively easily integrated with Google Earth KML, so layers and even entire maps created in a GIS can be exported into Google Earth. Of course, this is by no means the only format for distribution, but it is popular due to the familiar Google interface, ease in opening a KML file (once Google Earth is installed on a computer, just double-click and GE will open and zoom to the KML location), one file transfer (a KML is one file, whereas a GIS layer is composed of many files) via e-mail or download, and adjustable transparency so underlying aerial imagery can be used to give context to the map. As you can see from Figure 1:16, a decision-maker can look at this map, zoom in on certain areas, and estimate the numbers of surge patients and their socio-economic context. This approach provides additional planning information such as whether or not multi-lingual staff will be required or if any pre-existing health burdens can be anticipated. This is a powerful advance for understanding disaster, driven by the utility of spatial thinking and maps.

Hopefully this chapter will have shown the importance of geography in disasters—both in terms of the physical process and human dimension. You should now be familiar with a few geographic concepts, and general approaches to solving spatial problems. We have also briefly introduced spatial data collection and communication. In order to achieve all of these aspects, we need to use a GIS—and the next chapter will continue our introduction of this spatial software tool.