Emergency Response via Inland Waterways

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Abstract

This research investigates the feasibility of using inland waterway transportation to provide emergency medical response to catastrophic events. Limited resources are available to provide general hazard relief across much of the United States. Inland waterways can provide access for equipment and people when other means of transportation are unavailable due to capacity constraints or destruction. Specific research questions include: (1) what are the emergency response capabilities of inland waterways, (2) what is the feasibility of providing emergency medical services via barge, (3) which types of communities could benefit from such a service, and (4) for which types of emergencies could medical response via barge be appropriate. This research is accomplished through literature review, feasibility analysis, and a case study based on the state of Arkansas. A Waterway Emergency Medical Service (WEMS) index is developed to guide emergency planners in evaluating the feasibility of incorporating emergency medical response via inland waterways into their emergency operations plan (EOP).

1 Introduction

1.1 Research Motivation

Many emergency operations plans (EOPs) are based on the assumption that all standard means of transportation will be available and feasible when an emergency occurs. In many cases, however, the disaster that initiates the EOP may disable emergency vehicles or destroy the roads or bridges that are vital to responding to the emergency. As transportation security professionals prepare contingency plans for emergency response, it is important to recognize the resource offered by the nation's inland waterways. For many communities, inland waterways can provide access for equipment and people when other means of transportation are unavailable due to capacity constraints or destruction. Inland waterways may be especially useful for emergency medical response in rural areas. Because of limited resources in rural communities, emergency planners must take an all-hazards approach to emergency planning across large geographical areas. Inland waterways could be used for medical response to a variety of emergencies across a large area. For example, there are over 1,000 miles of navigable waterways in the state of Arkansas. These waterways could be used to assist in response to a catastrophic event such as a New Madrid earthquake in the northeast corner of the state.

Particular research questions include: (1) what are the emergency response capabilities of inland waterways, (2) what is the feasibility of providing emergency medical services via barge, (3) which types of communities could benefit from such a service, and (4) for which types of emergencies could medical response via barge be appropriate. This research is relevant for emergency management professionals of communities with access to inland waterways. A literature review of the relevant work in this area and interviews with emergency management personnel were conducted. The capacity and usability of inland waterways as a means of emergency medical response for a variety of catastrophic events are assessed and reported. In addition, a Waterway Emergency Medical Service (WEMS) index is developed that guides emergency planners in evaluating the feasibility of incorporating emergency medical response via inland waterways into their EOPs. A case study based on the state of Arkansas is conducted to exemplify use of the WEMS index.

1.2 Research Objectives

The overall goal of this research is to conduct a feasibility analysis of improving emergency preparedness and disaster relief through utilization of inland waterway transportation. The primary objectives of this study are to:

1) Assess the current and potential capabilities of inland waterways to assist in emergency medical response.

   While the nation has thousands of miles of navigable inland waterways, not all are accessible year round. Also, response time will be affected by the average velocity of the response vessel as well as the water conditions for a given day. Further investigation of these factors will help to assess the emergency response capabilities of inland waterways for a given community. In addition, this research provides insight into the actual number of communities that have access to inland waterways and could potentially benefit from waterway emergency medical response.

2) Determine which types of communities would most likely benefit from waterway-based medical assistance and which types of catastrophic events would most likely require such assistance.

Because of the nature of inland waterways, it is not feasible that every community would benefit from waterway-based medical assistance. Many communities do not have a navigable inland waterway within hundreds of miles. However, areas that do have access to navigable waterways may stand to benefit from emergency medical response via those waterways. Our investigation reveals that the effective range of a navigable waterway for emergency medical response is somewhat subjective. We believe travel time to be the primary factor for determining a community's access to a waterway. Specifically, we believe that any community that is not within three hours (assuming a thirty-five mile per hour travel time) of a navigable waterway does not stand to benefit from medical services provided by a barge. The three hour threshold was set because we believe that if disaster victims are required to travel more than three hours to reach a medical barge, they would likely find nearer established medical facilities in other areas. This metric is useful for pinpointing which communities are best served by a medical barge. In addition, waterway-based medical response is obviously limited to certain types of emergencies. Communities may spend weeks or even months recovering from large scale emergencies such as tornadoes or earthquakes. Because barges have a relatively slow response time but can provide additional capacity for treating victims, this type of emergency is better suited for waterway medical response.

3) Develop an index to measure the usefulness and feasibility of providing waterway-based medical assistance to a given community and provide guidelines for calculating this index.

The goal is to provide emergency planners with a potentially unconsidered option for emergency medical response via inland waterways. A WEMS index based on measureable factors including *Accessibility to Navigable Inland Waterway*, *Proximity to*

Barge Origin, Population Demands, Social Vulnerability, Risk of Disaster, *and Limited Access to Medical Services* is developed to help planners assess the feasibility of using inland waterways to provide emergency medical assistance to their communities. Guidelines to calculate this index will help authorities plan and adequately prepare for a disaster in their community.

1.3 Research Contributions

This research makes two primary research contributions: 1) to conduct the first known systematic feasibility assessment of using inland waterways to provide emergency medical response and 2) to provide a measurable index to allow emergency planners to evaluate the feasibility of using inland waterways for emergency medical response in their community. The research provides emergency planners with insight into a previously unconsidered method for emergency response that could prove a useful addition to many EOPs.

2 Literature Review

2.1 Emergency Planning

The United States has always placed a strong emphasis on emergency preparedness. Preparedness, as defined by the Department of Homeland Security (DHS), “addresses the full range of capabilities to prevent, protect against, and respond to acts of terror or other disasters” (Jenkins, 2006A). The Robert T. Stafford Disaster Relief and Emergency Assistance Act, signed into law November 23, 1988, states that federal, state, and local governments share a joint responsibility for emergency preparedness. The Act further states that the federal government should provide “necessary direction, coordination, and guidance” to ensure that an all-hazards emergency preparedness system is in place (Federal Emergency Management Agency (FEMA), 1988).

In response, the Federal Emergency Management Agency (1996) developed a comprehensive, risk-based, all-hazard approach to emergency planning entitled *Guide for All-Hazard Emergency Operations Planning* (*Guide*). Its purpose is to provide aid to state and local governments in developing a custom all-hazard EOP for their respective areas of jurisdiction. The advantage of an all-hazards approach to emergency preparedness is that it ensures “that the nation is better prepared for terrorist events while simultaneously better preparing itself to deal with natural disasters” (GAO, 2005). The *Guide* details the components necessary for a good EOP, and it identifies key personnel and resources that may be needed. The recommendations provided by the *Guide* are centered around the basic goal of emergency preparedness, which “is that first responders should be able to respond swiftly with well-planned, well-coordinated, and effective actions that save lives and property, mitigate the effects of the disaster, and set the stage for a quick, effective recovery,” as stated in the report *Emergency Preparedness and Response* (Jenkins, 2006A). The July 19, 1989 crash of United Airlines Flight 232 provides an excellent example of how an effective and practiced emergency response plan can save lives. The established Sioux City emergency plan was rehearsed annually with various disaster scenarios, enabling rescuers to “discern the weaknesses in their coordination efforts” and establishing trust among the different branches (Larson, 2006). During the actual emergency, rescuers “were so familiar with the plan that they never needed to refer to it.”

Since the terrorist attacks of September 11, 2001 and the devastating Hurricane Katrina of 2005, emergency planning and response have become even higher priorities for the Federal government. With such a strong emphasis being placed on emergency preparedness, many emergency planners are seeking to identify areas in need of improvement. A search of emergency planning literature reveals *Catastrophic Disasters*, a report from the United States Government Accountability Office (GAO), which discusses the Federal government's response to Hurricane Katrina and identifies areas of improvement in the nation's "readiness to respond to a catastrophic disaster" (GAO, 2006). Emphasizing the importance of emergency planning, the *Catastrophic Disasters* report states that "catastrophic disasters involve extraordinary levels of mass casualties, damage, or disruption that likely will immediately overwhelm state and local responders, circumstances that make sound planning…all the more crucial." *Catastrophic Disasters* goes on to state that to improve the nation's preparedness for and response to disasters, plans should "detail what needs to be done, by whom, how, and how well" (GAO, 2006). This point is reiterated in another GAO report titled *Homeland Security: Assessment of the National Capital Region Strategic Plan*, which notes that one desirable characteristic of a strategic plan is identification of "organizational roles, responsibilities, and coordination" (Jenkins, 2006B).

2.1.1 Transportation in Emergency Planning

Transportation plays a key role in emergency planning. The movement of supplies and people is a vital component of any emergency response effort, as seen in FEMA's *Guide*. A key component of an EOP's basic plan is *Administration and Logistics*, a section that provides policies for managing the flow of resources such as materials and people. The *Guide* also lists *Evacuation* as one of the functional annexes that should exist in an effective EOP (FEMA, 1996). Effectively moving large groups of people during an emergency situation involves careful transportation planning. *Search and Rescue* is another critical part of any EOP. The *Guide* states that search and rescue teams are responsible for assisting trapped or injured persons, providing first aid, and “assisting in transporting the seriously injured to medical facilities.” Emphasizing the significance of transportation, a GAO report titled *Agency Plans, Implementation, and Challenges Regarding the National Strategy for Homeland Security* identifies transportation as an important focus of the country’s critical infrastructure protection effort (GAO, 2005).

Ambulance availability, ambulance coordination, and patient transportation are other examples of the importance of transportation in emergency preparedness, and each should also be considered when creating an EOP. Proper planning in this area can save lives. This is demonstrated by an article from the emergency planning literature that analyzes responses to several major emergencies in recent history. In the aftermath of the 1989 Crash of United Airlines Flight 232 at the Sioux City airport in Iowa, excellent planning by police and emergency medical personnel expedited the transfer of victims injured during the crash. Mutual aid agreements between Sioux City and its neighboring communities allowed all available emergency vehicles in the surrounding area to be ready and waiting at the airport to transport injured passengers (Larson, 2006). In addition, police set up road blocks on the highway between the airport and the hospital, allowing the ambulances to travel much faster. “The first victims arrived at the hospital less than 16 minutes after the plane crashed while the last victim arrived within 40 minutes of the crash” (Larson, 2006). Proper planning in the area of transportation allowed authorities to respond quickly and efficiently, thus mitigating the effects of this deadly disaster.

While the importance of transportation is apparent in much of the emergency planning literature, very little documentation exists on emergency planning with a focus on transportation. The literature does reveal, however, that most EOPs are based on the assumption that all standard means of transportation will be available to respond to a disaster. However, tornadoes, mudslides, and earthquakes can destroy vital roadways and bridges and disable emergency vehicles. There is little mention of contingency planning if the standard modes of transportation are destroyed or disabled.

2.1.2 Emergency Planning in Rural Communities

There is limited research on emergency planning for rural areas. This may be due to the relatively low population levels of rural areas when compared to urban areas. The literature seems to focus on high population areas where disasters are likely to affect large amounts of people. However, according to the Economic Research Service (ERS) of the United States Department of Agriculture (USDA), nonmetropolitan areas in the U.S. account for 2,052 counties, contain seventy-five percent of the Nation's land, and include seventeen percent of the U.S. population (ERS, 2003). Because these areas represent such a large physical portion of the country and are home to nearly fifty million U.S. citizens, emergency planning has an obvious and important role in rural communities. In addition, rural areas must be able to adequately handle a “migration of large populations displaced from urban areas” after a disaster (Furbee et al., 2006). While emergency planning is important in both urban and rural settings, the planning process is different for each area.

Challenges exist in rural emergency planning because rural areas differ greatly from urban areas. For rural areas, population densities are lower, mass transit is virtually non-existent, and resources are often more scarce. Even among rural areas, differences exist. Some rural areas lie in a flood plain, others lie on a fault line, and some lie near both. Some rural areas are manufacturing communities, while others are agriculture-based. The dissimilarities between rural and urban environments suggest that emergency plans for rural areas should likely differ from emergency plans for urban areas. Further, differences are likely to exist even among rural emergency plans.

Further search of the literature reveals discussions of the disaster preparedness of rural emergency medical services. A survey of rural emergency medical services (EMS) organizations across the country revealed that many of them would be quickly overloaded by any large scale disaster (Furbee et al., 2006). Most organizations surveyed placed a low priority on interacting with other disaster response organizations, instead placing priority on “basic staff training and retention.” With their limited resources, most rural EMS organizations prefer to focus on maintaining day-to-day operations rather than sink funds into planning for an event that may never occur. According to Furbee, et al. (2006), “there is no single standard that requires EMS organizations to have a disaster plan,” but even if a plan exists, there is no guarantee that it is adequate or even acceptable. The reality is that most rural medical services are not prepared for large scale disasters. The organizations surveyed reveal low confidence levels in their preparation for incidents involving a large number of victims. Suggestions have been made on how to improve readiness, but funding and other resources do not exist to implement the necessary changes. The researchers note that rural EMS organizations are further challenged by “increased reliance on volunteers, fewer healthcare professionals…less surge capacity, and greater distance from other needed resources.” A GAO (2005) report titled “Agency Plans, Implementation, and Challenges Regarding the National Strategy for Homeland Security” calls for “state and local governments to sign mutual aid agreements to facilitate cooperation with their neighbors in time of emergency.” Mutual aid agreements among smaller communities would allow emergency planners to pool their limited resources, providing more options for emergency response. The same GAO report further emphasizes the importance of these agreements, because although incident response "would occur at a local level, it could spread across local, state, and even national boundaries."

2.1.3 Challenges of Emergency Planning

Effective emergency planning is not an easy task. There are many challenges involved in planning for the preparedness, response, and recovery process. Cutter et al. (2003) focus specifically on the social impacts of disasters, arguing that some communities are more socially vulnerable than others. Social vulnerability is described as the social, economic, demographic, and housing characteristics that influence a community's "ability to respond to, cope with, recover from, and adapt to hazards" (Cutter et al., 2003). Each factor affects the vulnerability of each community differently. Because every community is unique, differences in these factors result in a different social vulnerability index (SoVI) for each community, thus further complicating the emergency planning process.

Additional challenges arise when adapting an all-hazards approach to emergency planning. These include proper identification of potential emergencies and the requirements for appropriate response, "assessing current capabilities against those requirements," and developing effective and coordinated plans among first responders (GAO, 2005). In its response to the GAO report *Catastrophic Disasters* (2006), DHS comments on the difficulties faced in emergency planning. "Since resources are finite…tough choices must be made about how to allocate the human and financial resources available to attain the optimal state of preparedness." The same report identifies another problem faced in emergency planning. As indicated by the varying SoVIs of U.S. communities, the diversity of areas across the United States complicates large scale emergency planning. "Because different states and areas face different risks, not every state or area should be expected to have the same capability to prepare for a catastrophic disaster" (GAO, 2006). With each community having its own set of unique characteristics, it is important for emergency planners to consider all the resources that may be available to their communities. A community with access to a navigable river, for example, should consider the waterway's potential use as a means of transportation.

2.2 Emergency Medical Response

The FEMA's *Guide* (1996) states that a community's EOP should detail the steps for the health and medical aspects of responding to an emergency. Communities should have preparations for health and medical services including "emergency medical services (EMS), hospital, public health, environmental health, mental health, and mortuary services. The activities associated with these services include treatment, transport, and evacuation of the injured; disposition of the dead; and disease control activities."

Emergency medical response is clearly dependent on transportation. In order for first responders to reach disaster victims quickly, nearly every mode of transportation may be utilized. County roads, city roads, highways, and bridges are used every day for emergency medical response. Fire trucks, ambulances, buses, tractor-trailers, off-road vehicles, and even helicopters are used to transport emergency workers, accident victims, and medical supplies. The underlying assumption for everyday emergency medical response is that these common forms of transportation will be readily available. But what if a catastrophic disaster renders the roadways unusable? What if an earthquake destroys the only bridge on a major thoroughfare? What if thousands of isolated people need medical assistance and only a few helicopters are available to transport victims to medical centers? Instead of trying to get the victims to a medical center, why not bring the medical center to the victims via inland waterways? A waterway emergency medical service could do just that.

2.3 Inland Waterways

According to the Bureau of Transportation Statistics (2002), the United States has over 26,000 miles of navigable waterways that are used to transport millions of tons of cargo every day. In fact, the Bureau (2008) also states that United States waterborne trades over inland waterways amounted to 627.6 million short tons in 2006 alone. The nation's waterways are used to transport approximately 20% of America's coal, which produces 10% of all electricity used annually in the U.S. Waterways are also used to transport 40% of U.S. petroleum and petroleum products and 60% of the nation's grain exports. The water transportation industry accounts for about 15% of the nation's commerce but is responsible for only 2% of America's freight costs (Morton, 2002).

Inland waterways are a tremendous asset to the U.S., providing the most economically and environmentally sound mode of moving goods and commodities. According to Inland Rivers, Port, & Terminals, Inc. (2009), waterways are the oldest mode of heavy commercial and industrial transportation. Spurred by the new demands of the Industrial Revolution in the 1700s, both Europe and America created an inland network of water canals. A horse or mule on the shore pulling a barge through a canal could tow up to fifty times more weight than on a wagon on the road. This same energy efficient principle still holds true today, allowing barges to carry nearly sixty times more cargo than tractor trailers and about fifteen times more cargo than railcars. These relationships are graphically represented in Figure 1 (Nachtmann, 2001).

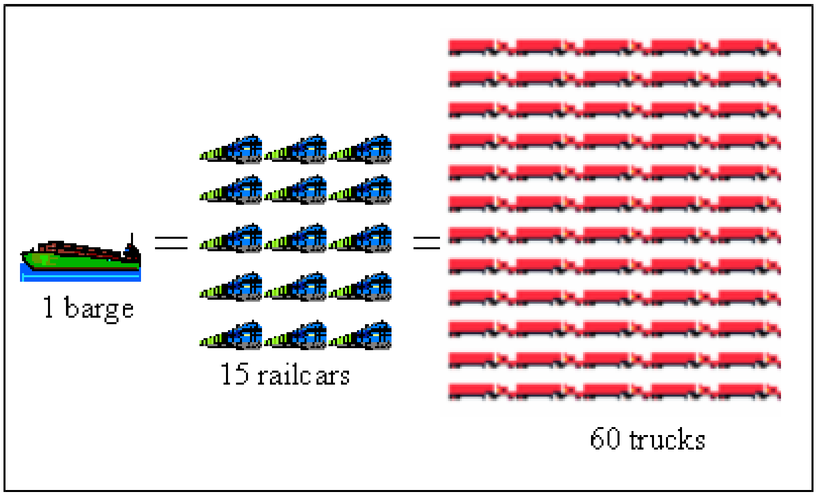


Figure 1: Cargo Capacity

Waterways offer a very cost-effective mode of transportation. The typical cost per ton-mile for a barge is approximately $1.00, compared to $2.53 for rail, and $5.35 for trucking, as seen in Figure 2 (Nachtmann, 2001). Water transportation also offers a fuel efficiency advantage over rail and truck transportation. The number of miles one ton of cargo can be carried per gallon of fuel by a barge is 514 miles, as compared to 202 miles by train, and fifty-nine miles by truck, as seen in Figure 3 (Nachtmann, 2001). Other benefits of water transportation include:

- It is the safest way to ship chemicals and toxic materials.
- It does not contribute to noise pollution.
- It does not contribute to land congestion.
- Its economical shipping costs reduce raw material costs and thus the cost of final consumer goods.
- Industries that use barge transportation typically pay above average wages (Nachtmann, 2001).

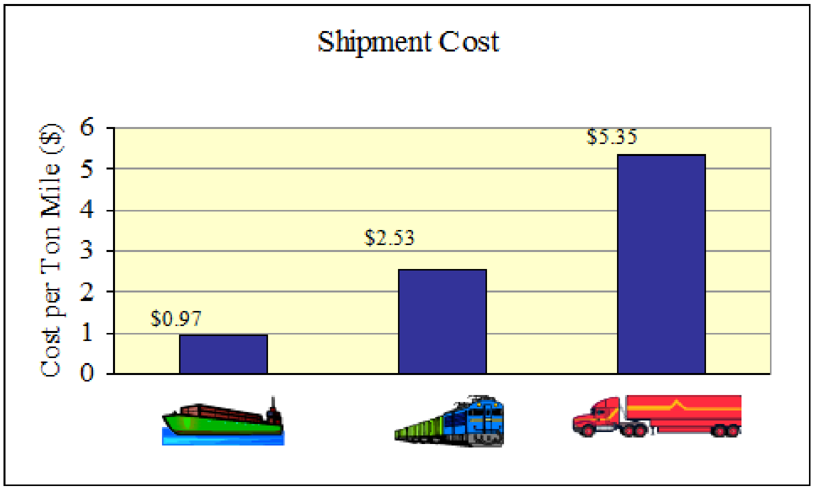


Figure 2: Shipment Cost

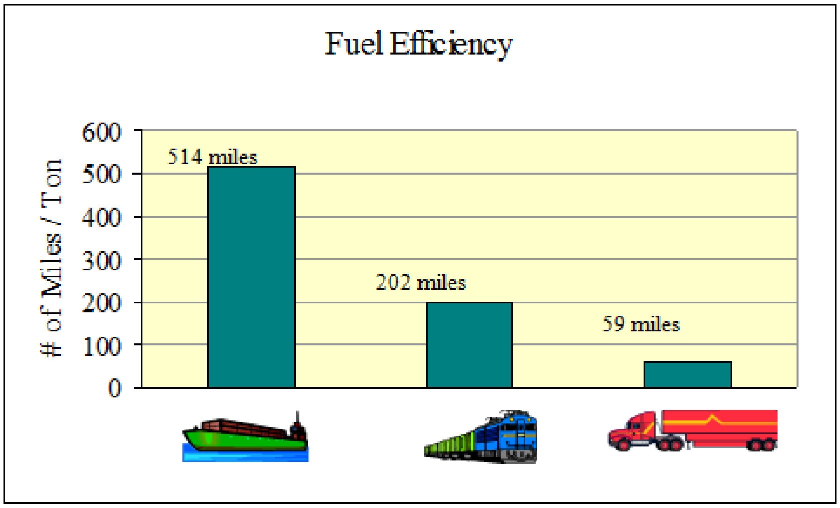


Figure 3: Fuel Efficiency

2.4 Medical Response via Barge

While most barges are typically used for transporting goods along waterways, history reveals that some vessels have been used to provide medical services. In New York City, a barge served as a floating hospital, providing free medical and dental care to low income families from 1866 until just recently. Tickets were mailed to eligible families, and the vessel would set sail during the summer months while children were out of school (New York Times, 1988). Barges have also been used to provide medical services to the military. During World War I, British troop casualties were evacuated via floating hospital barges. The slow speed of the vessel actually proved to be useful for the injured troops, allowing them to recover before arriving at their destination (Quaranc, 2009).

Even in recent times, the idea of floating hospitals is being put to practical use. Using marine vessels to provide medical care to disaster victims and the poor is becoming quite common. In May 2008, victims of the Burmese cyclone received medical care on board three ships set aside for such a purpose. Each boat was equipped with a clinic room, medicines, and a dental chair (Swe, 2008). In addition, the humanitarian organization known as Marine Reach owns a floating hospital that provides services to poor, isolated communities in the Pacific Islands and Southeast Asia (Marine Reach, 2009). Another example is the 522-foot floating hospital known as the Anastasis, shown in Figure 4, which cruises the west coast of Africa providing medical services to impoverished people (Thomas, 2003).


Photo courtesy of labnews.co.uk

Figure 4: Floating Hospital Anastasis.

Perhaps the most impressive floating hospital is the USNS Comfort, shown in Figure 5. Comfort is a 900-foot, ten-deck vessel with 1,000 hospital beds. The ship and her crew assisted with Hurricane Katrina disaster relief efforts. The vessel is capable of handling all complicated procedures, with the exception of heart surgery and organ transplant. It has CAT scan facilities, twelve operating theaters, a blood bank, a dental facility, and even a manufacturing facility for eyeglasses. It staffs over 1,200 people, and was converted from an oil tanker to a floating hospital in 1983 (Singh, 2003).

Figure 5: USNS Comfort.

While each of these ships has provided medical services via ocean waters rather than inland waterways, each vessel represents a practical example of a floating hospital.

3 Methodology

3.1 Literature Review

As detailed in Section 2, a literature review of related work was completed. Relevant literature was reviewed in order to assess the current and potential capabilities of inland waterways to assist in emergency response. The information obtained from the literature review was synthesized to answer three research questions: (1) which communities are most likely to benefit from inland waterway-based emergency response, (2) which types of catastrophic events are most likely to occur in these communities, and (3) which types of catastrophic events could most likely require such assistance. The answers to these research questions are used to conduct a feasibility analysis as described in Step 3.

- Which types of communities would benefit from waterway-based emergency medical response?

  - Communities that are isolated from major population centers may not have access to the emergency services and medical facilities that are readily available in large cities. If these types of communities are located near inland waterways, then they may be candidates for emergency medical response via those inland waterways. Communities that are large enough to have emergency services easily accessible and communities that are large distances from inland waterways are less likely to benefit from waterway-based medical assistance. However, waterway-based response could prove beneficial to communities that depend heavily on non-waterway transportation means if disruption occurs to transportation infrastructure such as major interstates or bridges.
- What is the possibility of disaster occurrence in the serviceable areas?
  - Once candidate communities are identified, it is also necessary to identify the possible catastrophic emergency events that could occur in those areas. Knowing which communities are likely to have certain emergencies is useful for determining the feasibility of barge response for that community. This information may be readily available or may need to be derived. In our case study of Arkansas, for example, we use historical tornado data to estimate the risk of a violent tornado occurring in each county.
- For which events is inland waterway response appropriate?
  - Based on the capabilities of barges, we were able to establish that barge response would only be effective for certain types of disasters. For example, the average velocity of a typical barge will limit the effectiveness of an inland waterway

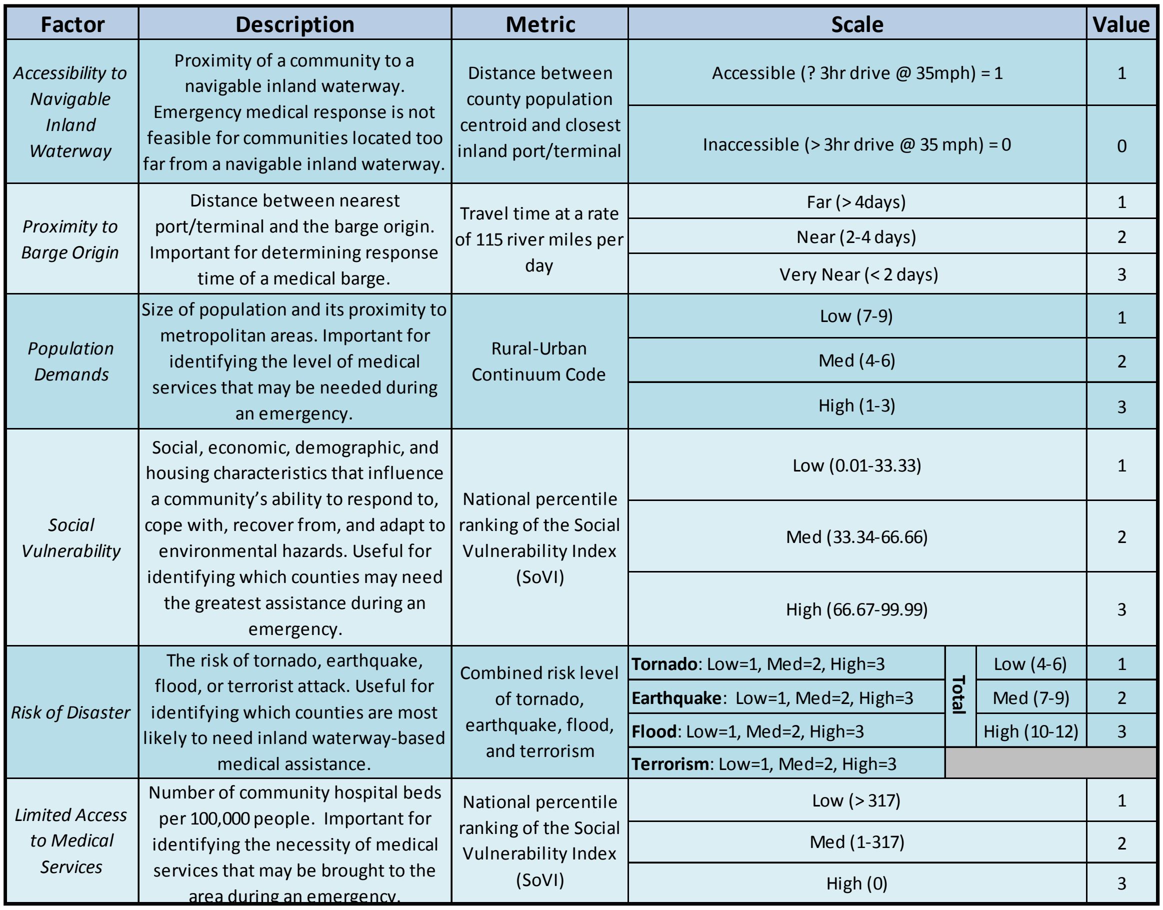
emergency response to a fire. The slow velocity better suits a barge to deliver medical supplies, provide relief to overwhelmed medical facilities, or even provide a sterile environment for on-site emergency surgeries during long-term recovery from a disaster. In general, disasters that require long term recovery, have large numbers of victims, or have victims that need non-urgent care lend themselves to barge response. A barge could not, however, efficiently respond to more urgent emergencies such as a fire or immediate medical concerns.

3.2 Waterway Emergency Medical Service (WEMS) Index

We conducted a feasibility analysis of providing disaster medical relief by barge via inland waterways based on the information obtained from Section 3.1. Our goal for the feasibility analysis was the development of a set of factors that describe the effectiveness of waterway emergency response to a given community. The factors will be combined into a Waterway Emergency Medical Service (WEMS) Index that will guide emergency planners in determining the feasibility of using barge-based medical response in their emergency planning.

The key to determining the feasibility of the emergency medical response barge transportation is to determine how effective the barge response could potentially be to a given community. We identified six factors that are important to determining a community's WEMS index value. Table 1 contains a description of each factor and its corresponding metric and scale that is used to compute a community's WEMS Index value. The WEMS index represents the extent to which a particular community could potentially benefit from inland waterway emergency medical response.

Table 1: WEMS Index Factors



<table>
<tr><th>Factor</th><th>Description</th><th>Metric</th><th colspan="3">Scale</th><th>Value</th></tr>
<tr><td rowspan="2">Accessibility to Navigable Inland Waterway</td><td rowspan="2">Proximity of a community to a navigable inland waterway. Emergency medical response is not feasible for communities located too far from a navigable inland waterway.</td><td rowspan="2">Distance between county population centroid and closest inland port/terminal</td><td colspan="3">Accessible (? 3hr drive @ 35mph) = 1</td><td>1</td></tr>
<tr><td colspan="3">Inaccessible (> 3hr drive @ 35 mph) = 0</td><td>0</td></tr>
<tr><td rowspan="3">Proximity to Barge Origin</td><td rowspan="3">Distance between nearest port/terminal and the barge origin. Important for determining response time of a medical barge.</td><td rowspan="3">Travel time at a rate of 115 river miles per day</td><td colspan="3">Far (> 4days)</td><td>1</td></tr>
<tr><td colspan="3">Near (2-4 days)</td><td>2</td></tr>
<tr><td colspan="3">Very Near (< 2 days)</td><td>3</td></tr>
<tr><td rowspan="3">Population Demands</td><td rowspan="3">Size of population and its proximity to metropolitan areas. Important for identifying the level of medical services that may be needed during an emergency.</td><td rowspan="3">Rural-Urban Continuum Code</td><td colspan="3">Low (7-9)</td><td>1</td></tr>
<tr><td colspan="3">Med (4-6)</td><td>2</td></tr>
<tr><td colspan="3">High (1-3)</td><td>3</td></tr>
<tr><td rowspan="3">Social Vulnerability</td><td rowspan="3">Social, economic, demographic, and housing characteristics that influence a community’s ability to respond to, cope with, recover from, and adapt to environmental hazards. Useful for identifying which counties may need the greatest assistance during an emergency.</td><td rowspan="3">National percentile ranking of the Social Vulnerability Index (SoVI)</td><td colspan="3">Low (0.01-33.33)</td><td>1</td></tr>
<tr><td colspan="3">Med (33.34-66.66)</td><td>2</td></tr>
<tr><td colspan="3">High (66.67-99.99)</td><td>3</td></tr>
<tr><td rowspan="4">Risk of Disaster</td><td rowspan="4">The risk of tornado, earthquake, flood, or terrorist attack. Useful for identifying which counties are most likely to need inland waterway-based medical assistance.</td><td rowspan="4">Combined risk level of tornado, earthquake, flood, and terrorism</td><td>Tornado: Low=1, Med=2, High=3</td><td rowspan="3">Total</td><td>Low (4-6)</td><td>1</td></tr>
<tr><td>Earthquake: Low=1, Med=2, High=3</td><td>Med (7-9)</td><td>2</td></tr>
<tr><td>Flood: Low=1, Med=2, High=3</td><td>High (10-12)</td><td>3</td></tr>
<tr><td>Terrorism: Low=1, Med=2, High=3</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Limited Access to Medical Services</td><td rowspan="3">Number of community hospital beds per 100,000 people. Important for identifying the necessity of medical services that may be brought to the area during an emergency.</td><td rowspan="3">National percentile ranking of the Social Vulnerability Index (SoVI)</td><td colspan="3">Low (> 317)</td><td>1</td></tr>
<tr><td colspan="3">Med (1-317)</td><td>2</td></tr>
<tr><td colspan="3">High (0)</td><td>3</td></tr>
</table>

- Accessibility to Navigable Inland Waterway

A community that is located hundreds of miles from the nearest navigable inland waterway does not stand to benefit significantly from WEMS. In contrast, a community that is located directly on a navigable river could potentially benefit greatly from waterway assistance in the event of a disaster. Although ground-based medical vehicles could possibly be transported and deployed by a barge, the effective range of the watercraft is still limited to navigable waterways. We consider medical assistance via an inland waterway to be infeasible if a community is located more than a three hour drive from the nearest navigable waterway with an assumed driving speed of thirty-five miles per hour.

For the purposes of calculating the WEMS index, the *Accessibility to Navigable Inland Waterway* factor is divided into two categories: Accessible (≤ 3 hours of driving time) and Inaccessible (> 3 hours of driving time). Counties classified as Accessible or Inaccessible receive a score of one or zero respectively.

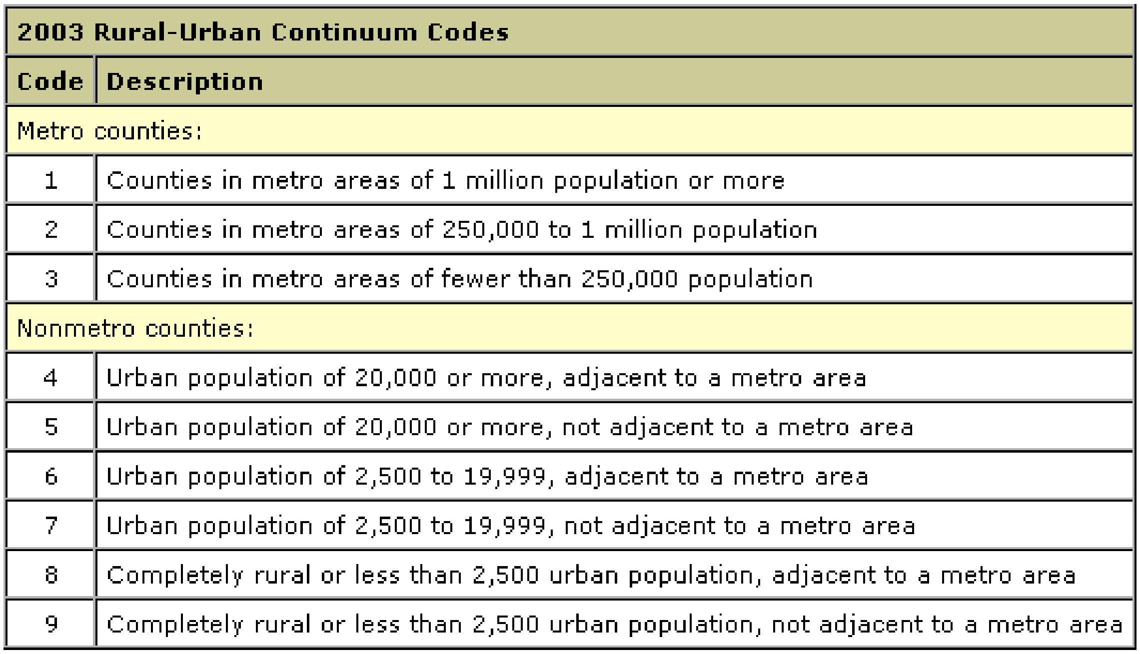
- Proximity to Barge Origin

  The index is affected by how quickly a barge can respond to an emergency or disaster in a given community. A barge is powerful yet slow. While it has the capability to move many tons of cargo along rivers, it can take several days to travel across a state. If an emergency occurs that requires a response within a matter of hours, a barge may only be able to assist if the community is within a few miles of the barge's home base. We define *Proximity to Barge Origin* as how long it takes the nearest medical barge to arrive at the nearest port on the nearest navigable waterway to the community. For the WEMS index, the *Proximity to Barge Origin* factor is divided into three categories: Very Near (< 2 days), Near (2 – 4 days), and Far (> 4 days). Communities classified as Very Near, Near, or Far will receive values of three, two, or one respectively.

- Population Demands

  It stands to reason that the larger the population, the larger the need for medical assistance during and after a disaster. This factor helps to establish the need for medical assistance based on a community's population and proximity to population centers. We define the metric for the *Population Demand* factor as the rural-urban continuum codes which are produced by the United States Department of Agriculture (USDA) Economic Research Service (ERS). "Rural-Urban Continuum Codes form a classification scheme that distinguishes metropolitan (metro) counties by the population size of their metro area, and nonmetropolitan (nonmetro) counties by degree of urbanization and adjacency to a metro area or areas. The metro and nonmetro categories have been subdivided into three metro and six nonmetro groupings, resulting in a nine-part county codification. The codes allow researchers working with county data to break such data into finer residential groups beyond a simple metro-nonmetro dichotomy, particularly for the analysis of trends in nonmetro areas that may be related to degree of rurality and metro proximity" (ERS, 2004B). Each county is given a code based on a scale from one to nine. The ERS defines each code in Table 2 (ERS, 2004B).

Table 2: Rural-Urban Continuum Codes



2003 Rural-Urban Continuum Codes	
Code	**Description**
Metro counties:	
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
Nonmetro counties:	
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

While the ERS provides codes on a scale of one to nine, for the *Population Demands* factor, we group the county codes into three categories: High (1-3), Medium (4-6), and Low (7-9). In order to calculate the WEMS index, counties classified as High, Medium, or Low will receive a score of three, two, or one respectively.

- Social Vulnerability

The social vulnerability of a community increases its need for emergency response services. "Generally defined, vulnerability is the potential for loss of life or property due to hazards. Social vulnerability is represented as the social, economic, demographic, and housing characteristics that influence a community's ability to respond to, cope with, recover from, and adapt to environmental hazards. County-level socioeconomic and demographic data were used to construct an index of social vulnerability to environmental hazards, called the Social Vulnerability Index (SoVI) for the United States based on 1990 data" (Hazards and Vulnerabilities Research Institute, 2008B).

The factors that are considered in the SoVI can be found in Table 3 (Cutter et al., 2003):

Table 3: SoVI Factors

Factor	Description
Personal Wealth	Wealth enables counties to absorb and recover from losses
Age	Children and elderly are most affected by disaster
Density of the Built Environment	Significant structural losses might be expected from a hazard event
Single-Sector Economic Dependence	Singular reliance on one economic sector creates economic vulnerability
Housing Stock and Tenancy	Quality and ownership of housing impacts displacement from damage
Race and Ethnicity	Racial and ethnic disparities affect access to resources and cultural difference
Occupation	Counties heavily dependent on lower wages service occupation might face slower recovery
Infrastructure	Infrastructure affects ability to divert resources in time of need

SoVI data is readily available for all U.S. counties (Hazards and Vulnerabilities Research Institute, 2008A). The database also provides the national percentile ranking for each county, which is used to categorize the counties for calculation of the WEMS index. For our purposes, a county with a Low, Medium, or High social vulnerability has a national percentile rank in the range of 0.01 to 33.33, 33.34 to 66.66, or 66.67 to 99.99 respectively. Counties with a Low, Medium, or High percentile are given scores of one, two, or three respectively.

- Risk of Disaster

Emergency medical barges may only be effective or viable for certain types of emergencies or disasters. If a certain community is not likely to have any of these specific occurrences, then it may not benefit from the services that could be offered by the barge. We divide the *Risk of Disaster* factor into four subfactors including the risk levels for tornado, earthquake, flood, and terrorist attack. The risk for each of the four disaster types can be categorized as low, medium, or high. A low rating is given a score of one, a medium rating is given a score of two, and a high rating is given a score of three. A community's overall *Risk of Disaster* level is determined by summing the individual values of its risk levels for tornado, earthquake, flood, and terrorist attack. For the WEMS index, the *Risk of Disaster* factor is divided into three categories: Low (4-6), Medium (7-9), and High (10-12). Communities with overall risk levels of low, medium, or high will receive scores of one, two, or three respectively. These risk levels can be determined by the emergency planner developing the WEMS Index based on their knowledge of their community's vulnerability to catastrophic events. Other types of disasters could be incorporated in the *Risk of Disaster* factor if deemed important.

- Limited Access to Medical Services

Limited Access to Medical Services measures the potential need for medical assistance from a barge based on the current availability of medical services in a community. Counties with limited access to medical services have a greater potential to benefit from an emergency medical barge. This factor measured as the number of community hospital beds per 100,000 persons in 2004 (U.S. Census Bureau, 2007). This data is readily available for each county in the United States. In year 2004, the average number of hospital beds per 100,000 persons nationwide was 317 per county. For our purposes, we are considering the counties with zero hospital beds per 100,000 persons to have a high potential of benefiting from a medical barge, counties with 1 to 317 (the nationwide average number of community hospital beds per 100,000 persons) to have medium potential, and counties with more than 317 to have low potential. Counties with a Low, Medium, or High potential are given scores one, two, or three respectively.

- WEMS Index Value

After a score has been determined for each of the factors for a given community, the overall WEMS Index value can be calculated. The equation for calculating the WEMS index is given by Equation 1.

$$WEMS\ Index\ Value = A(P + PD + V + R + M) \tag{1}$$

$$where\ A = Accessibility\ to\ Navigable\ Waterway\ score$$

$$P = Proximity\ to\ Barge\ Origin\ score$$

$$PD = Population\ Demands\ score$$

$$V = Social\ Vulnerability\ score$$

$$R = Risk\ of\ Disaster\ score$$

$$M = Limited\ Access\ to\ Medical\ Services$$

Note that there are exactly twelve possible values for the WEMS index: {0, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15}. An index value of zero indicates that the county is not within a three hour drive of a public port on a navigable inland waterway indicating that there is no potential for providing medical services via inland waterway for that county. An index value of five, six, or seven indicates that the county has low potential to benefit from inland waterway emergency medical services. For example, a county with a score of five has an inland waterway nearby but has a low population that is not adjacent to a metropolitan area, a low risk for disaster, a low SoVI, sufficient medical services, and is far from the barge starting point. An index value of eight, nine, or ten likely indicates that the county has medium potential to benefit from inland waterway emergency medical services. An index value of eleven, twelve, thirteen, fourteen, or fifteen indicates that the county has a high potential to benefit from inland waterway emergency medical services. For example, a county with an index value of fifteen has access to an inland waterway, has a large population or is adjacent to a metropolitan area, has a high risk for disaster, has a high SoVI, insufficient medical services, and is very near to the barge starting point.

4 WEMS Index Case Study of Arkansas

We performed a case study on the state of Arkansas to demonstrate the use of the WEMS index to evaluate the extent to which particular communities could potentially benefit from barge-based emergency medical assistance. The deliverable of this case study is an assessment of the WEMS index values for counties in the state of Arkansas.

4.1 Introduction to Arkansas

The state of Arkansas is comprised of seventy-five counties. According to the U.S. Census Bureau, the 52,000 square-mile state is home to more than 2,800,000 residents (U.S. Census Bureau, 2009). According to the Arkansas Waterways Commission (2009B), the state boasts over

1,000 miles of waterways across five rivers: the Arkansas, the Mississippi, the Ouachita, the Red, and the White.

The Mississippi River comprises the majority of the state's eastern border and connects the Great Lakes to the Gulf of Mexico, which eventually feed into the Atlantic Ocean. This gives Arkansas tremendous accessibility by inland waterway, making the rivers valuable transportation resources. In fact, a wide variety of products are shipped over these rivers, as seen in Figure 6 (Arkansas Waterways Commission, 2009A).

Figure 6: Arkansas Products Shipped via Inland Waterways

4.2 Data Collection

The first phase of the case study consisted of collecting the data necessary to compute the WEMS Index factor values. Table 4 contains a listing of the data sources that were used to compute the WEMS Index value for all Arkansas counties. Details of the data collection are provided in the remainder of this section.

Table 4: Data Sources for WEMS Factors

Factor	Metric	Source
Accessibility to Navigable Inland Waterway	Distance between county population centroid and closest inland port/terminal	Arkansas Waterways Commission (2009B), Google Maps (maps.google.com)
Proximity to Barge Origin	Travel time at a rate of 115 river miles per day	U.S. Army Corp of Engineers, Arkansas Waterways Commission
Population Demands	Rural-Urban Continuum Code	Economic Research Service (2004B)
Social Vulnerability	National percentile ranking of the Social Vulnerability Index (SoVI)	Hazards and Vulnerability Research Institute (2008A)
Risk of Disaster	Combined risk level of tornado, earthquake, flood, and terrorism	www.tornadoproject.com U.S. Geological Survey (2009A) Federal Emergency Management Association (2009) Arkansas Emergency Operations Plan (2007)
Limited Access to Medical Services	Number of Community Hospital Beds per 100,000 persons	U.S. Census Bureau (2007)

4.2.1 Accessibility to Navigable Inland Waterway

In order to calculate the drive times for the *Accessibility to Navigable Inland Waterway* factor, we first had to establish the origin and destination point for the residents of each county to travel to the nearest navigable waterway. We assume that barge access is limited to public ports (Fort Smith, Helena, Little Rock, Osceola, Pine Bluff, West Memphis, and Yellow Bend) and the starting location of the barge (Lake Dardanelle) that are accessible by rivers in Arkansas in this case study. This assumption limits the navigable rivers to the Arkansas and the Mississippi. It is feasible that emergency planners could get permission to access additional private ports and terminals but we chose to be conservative in our analysis. The origin point is the county's population centroid, which is defined as "the point at which an imaginary, weightless, rigid, and flat (no elevation effects) surface representation of the [county] would balance if weights of identical size were placed on it so that each weight represented the location o[f] one person" (U.S. Census Bureau, 2001). This data was retrieved for each county in Arkansas from the U.S. Census Bureau and can be found in Appendix I (U.S. Census Bureau, 2002). The destination point we established for each county is the nearest public port on the nearest navigable waterway as described above. This information is readily available from the Arkansas Waterways Commission and is depicted graphically in Figure 7 (Arkansas Waterways Commission, 2009B).

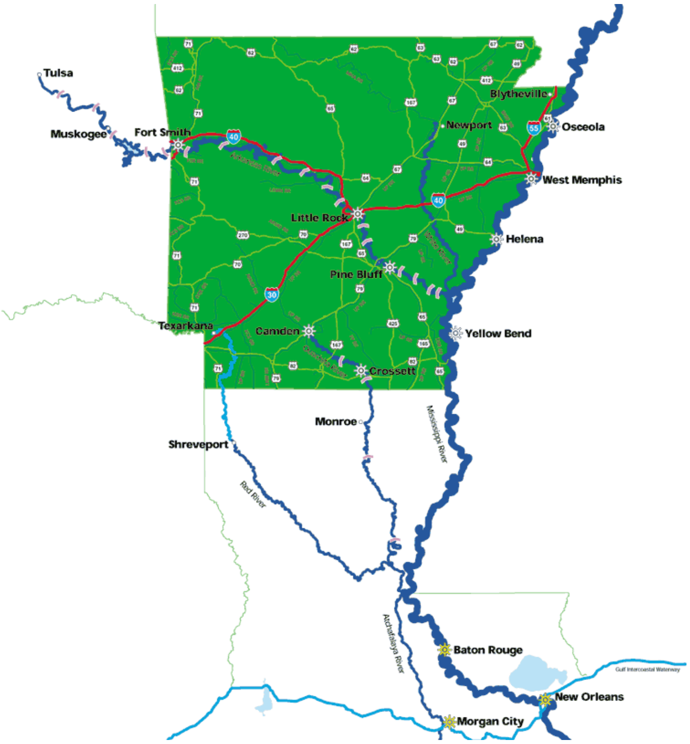


Figure 7: Arkansas Ports

Once the origin and destination points were identified for each county, Google Maps, an online mapping tool, was used to estimate the distance between the two points. The drive time was then found by dividing the distance by the assumed average travel speed of thirty-five miles per hour. Figure 8 shows which counties in Arkansas are within a three hour drive of a public port. The individual drive times for each county can be found in Appendix II.

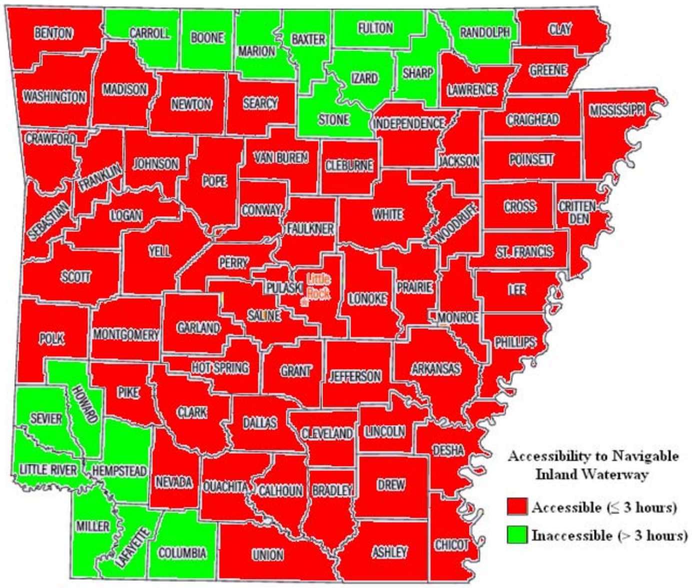


Figure 8: Waterway Access

4.2.2 Proximity to Barge Origin

In order to determine each county's proximity to a barge starting point, we estimated the barge travel time between each county's nearest public port and the primary storage location for the maintenance barge operated by the United States Army Corp of Engineers (USACE) in Arkansas. According to the USACE, Lake Dardanelle in Pope County near Russellville is the primary storage location for their maintenance barge. This barge is already fitted with electricity, air conditioning, and running water, so it is assumed this barge will serve as the emergency medical barge for the state of Arkansas.

We estimate that a barge can travel on average 115 miles per day. This estimate is based on estimated barge travel times and known river miles between major cities (Oklahoma Department of Transportation, 2000). Based on the estimated travel time, each county was categorized as being very near to (< 2 days), near to (2 – 4 days), or far from (> 4 days) the barge origin. Counties classified as very near, near, or far received scores of three, two, or one respectively. Figure 9 depicts the county scores graphically. The travel times between the Arkansas public ports and the barge starting point at Lake Dardanelle are given in Appendix III.

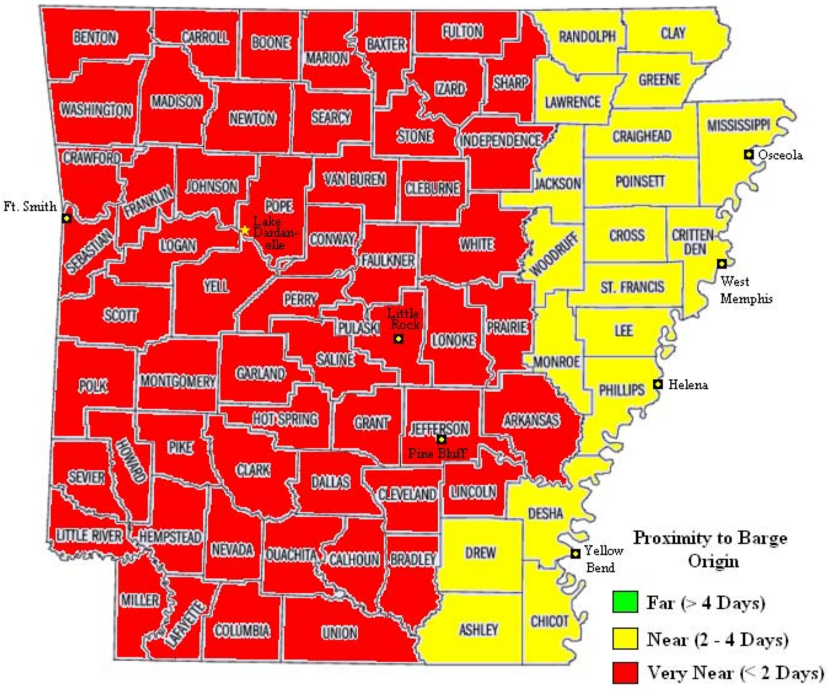


Figure 9: Proximity to Barge Starting Point

4.2.3 Population Demands

The rural-urban continuum codes for each county in Arkansas were provided by the ERS and can be found in Appendix IV (ERS, 2004A). Figure 10 shows the counties of Arkansas classified as high, medium, or low according to their need for medical assistance based on their rural-urban continuum code. Counties with high, medium, or low levels received scores of three, two, or one respectively.

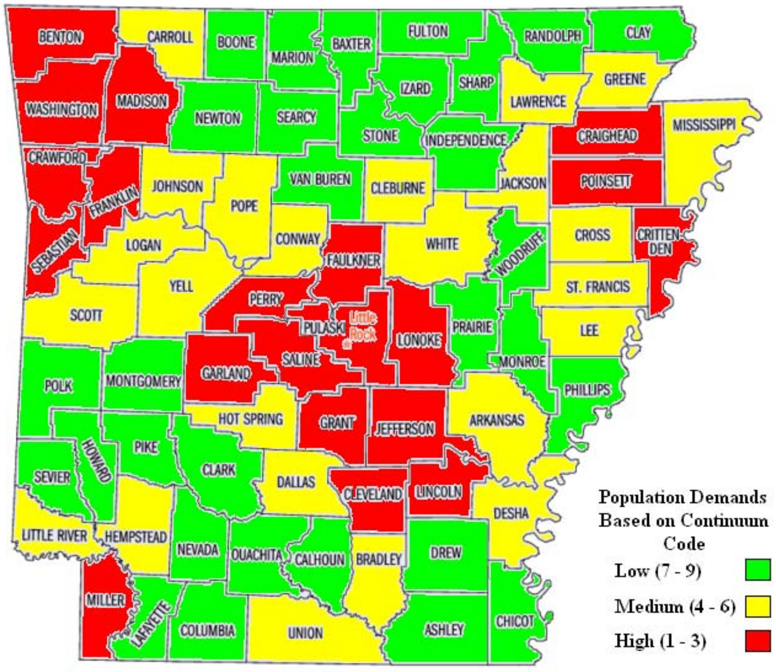


Figure 10: Rural-Urban Continuum Codes for Arkansas

4.2.4 Social Vulnerability

As discussed in earlier sections, a county's SoVI represents its "ability to respond to, cope with, recover from, and adapt to environmental hazards" (Hazards and Vulnerabilities Research Institute, 2008B). The SoVI value for each county in Arkansas was provided by the Hazards and Vulnerability Research Institute, as seen in Appendix V. In addition to the values, the database also provides the national percentile ranking for each county (Hazards and Vulnerabilities Research Institute, 2008A). We categorized the counties based on their national percentile. For the purposes of calculating the Social Vulnerability factor value, a low, medium, or high vulnerability is representative of percentiles from 0.01 to 33.33, 33.34 to 66.66, or 66.67 to 99.99

respectively. Counties with a low, medium, or high percentile are given values of one, two, or three respectively. The Social Vulnerability factor values for counties in Arkansas are depicted graphically in Figure 11.

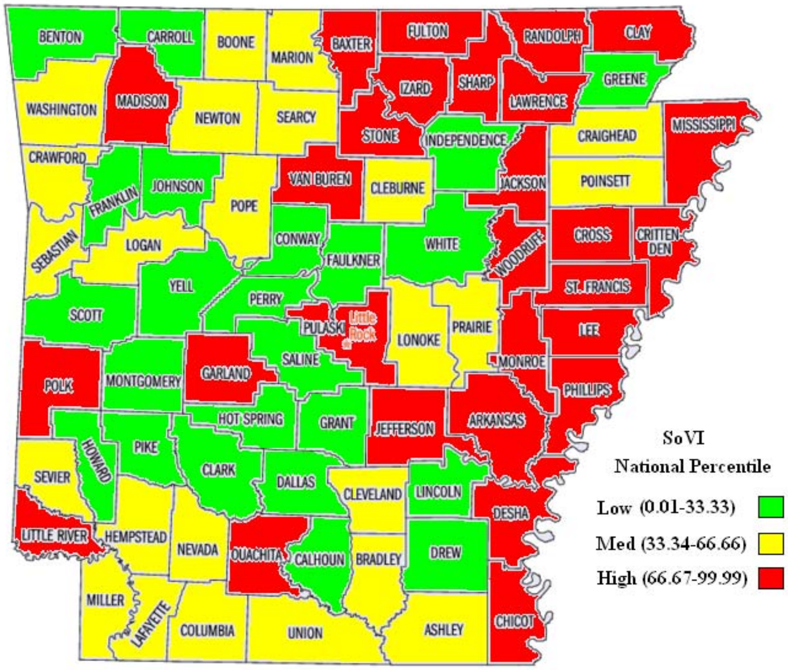


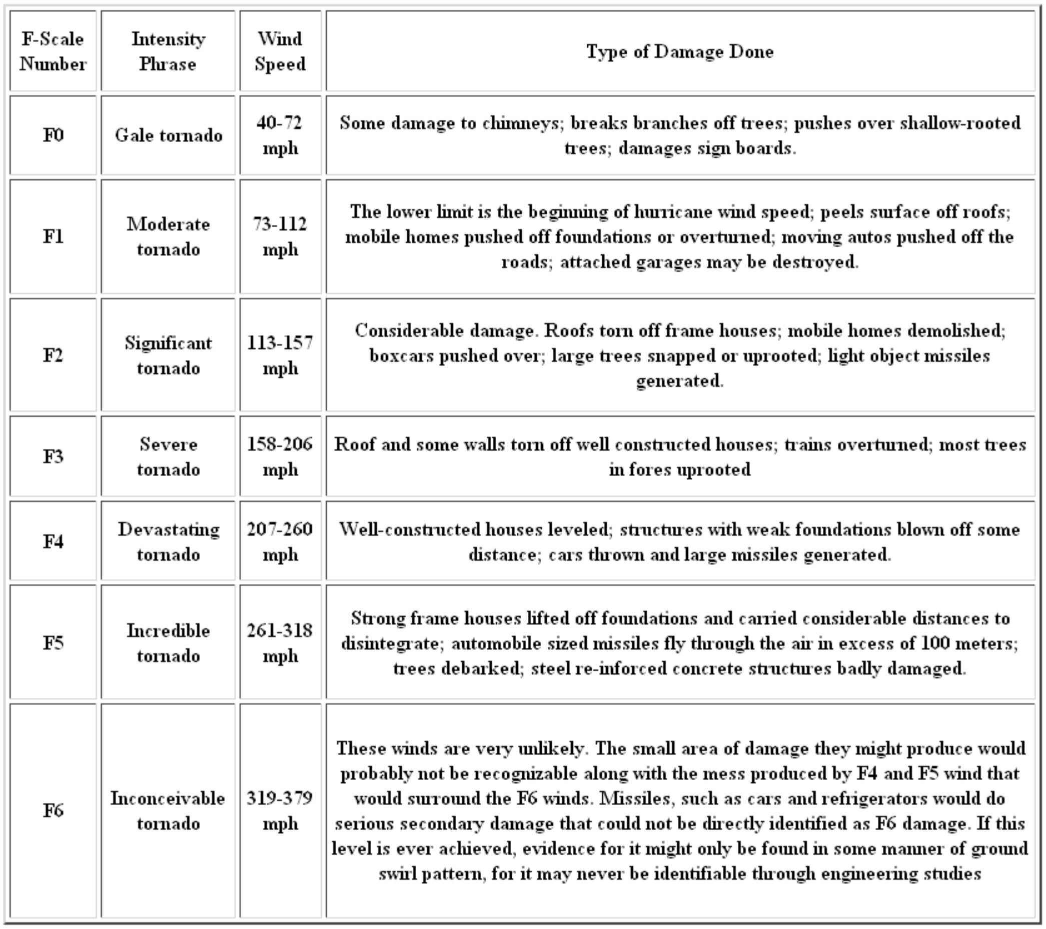
Figure 11: SoVI National Percentile

4.2.5 Risk of Disaster

When determining the risk of disaster for each county in Arkansas, data for tornadoes, earthquakes, floods, and terrorist attacks is needed. For the purposes of this study, we use historical tornado data to determine each county's risk level for violent tornadoes. A tornado's intensity is measured by its rating on the Fujita Scale, as seen in Table 5 (The Tornado Project, 1999). Using data from www.tornadoproject.com, we identified the total number of tornadoes and their Fujita Scale ratings for each county in Arkansas from 1950 to 1995. This website indicated that 67% of tornado-related deaths are caused by F4 and F5 tornadoes, 29% are caused by F2 and

F3 tornadoes, and only 4% are caused by F0 and F1 tornadoes, as seen in Figure 12 (The Tornado Project, 1999).

Table 5: Fujita Scale Description



F-Scale Number	Intensity Phrase	Wind Speed	Type of Damage Done
F0	Gale tornado	40-72 mph	Some damage to chimneys; breaks branches 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 the roads; attached garages may be destroyed.
F2	Significant tornado	113-157 mph	Considerable damage. Roofs torn off frame houses; 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 fores 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-inforced 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 identified 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

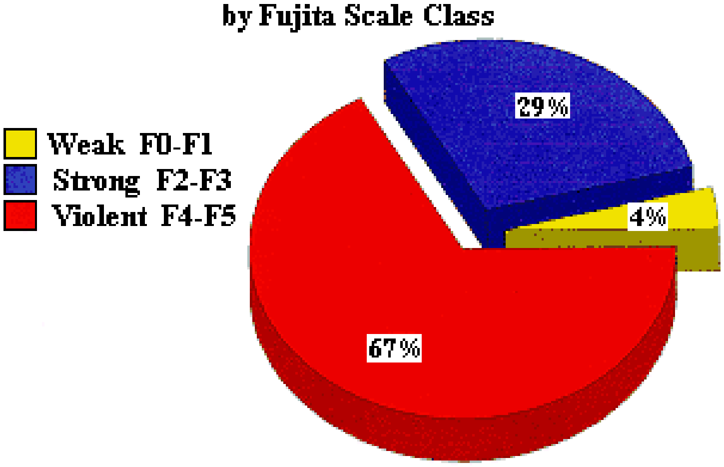


Figure 12: Percent of Tornado Related Deaths 1950-1994

Using this information about tornado-related deaths, we weighted the total number of F0 and F1 tornadoes, F2 and F3 tornadoes, and F4 and F5 tornadoes by 4%, 29%, and 67% respectively, and then summing overall to gain a “tornado score” for each county, as described in Equation 2. For example, Table 6 gives the historical tornado data for Howard County.

$$[0.04(F0 + F1)] + [0.29(F2 + F3)] + [0.67(F4 + F5)] = Tornado\ Risk\ Score \quad (2)$$

where F0, F1, F2, F3, F4, and F5 represent the county’s total number of F0, F1, F2, F3, F4, and F5 tornadoes respectively.

Table 6: Historical Tornado Data for Howard County Arkansas

County	Tot	F0	F1	F2	F3	F4	F5	Score
Howard	18	6	5	4	1	2	0	**3.23**

In order to calculate the score for Howard County, we used the tornado data from Table 6 and applied it to Equation 2.

$$[0.04(6 + 5)] + [0.29(4 + 1)] + [0.67(2 + 0)] = 3.23$$

The scores for each county were then categorized as low risk (0 to 2.49), medium risk (2.50 to 4.99), or high risk (≥5.00). Low risk counties received a tornado subfactor value of one, medium risk counties received a tornado subfactor value of two, and high risk counties received a tornado subfactor value of three. The values for each county can be found in Appendix VI (The Tornado Project, 1999). The results of the tornado risk analysis are shown graphically in Figure 13.

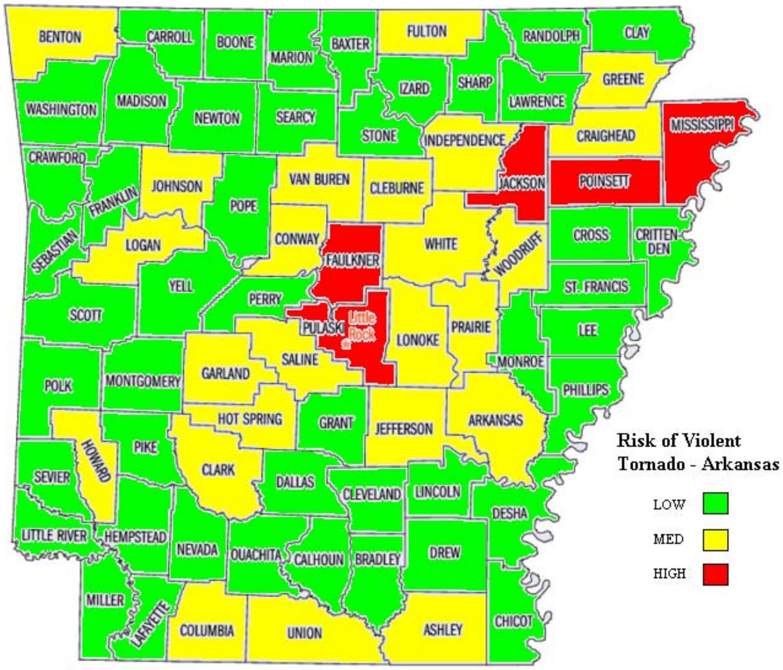
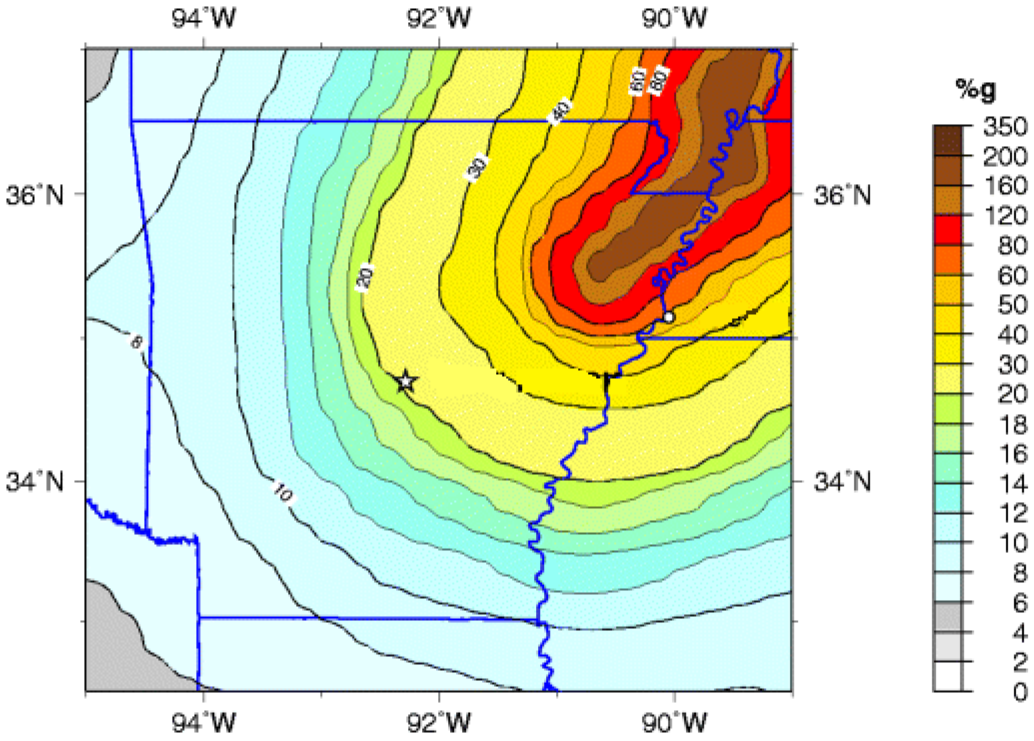


Figure 13: Risk of Violent Tornado

Earthquakes are capable of causing significant damage to ground structures and roads. Earthquakes have also been known to initiate other natural disasters including landslides and tsunamis. A powerful earthquake could easily disrupt standard means of transportation, inhibiting emergency workers from reaching victims of the disaster. Having waterway-based medical assistance available could serve to mitigate the effects of the earthquake.

In order to determine each county’s risk for earthquake, we gathered information on the seismicity of the state of Arkansas. The U.S. Geological Survey (USGS) measures seismicity in terms of peak acceleration during an earthquake. “During an earthquake when the ground is shaking, it also experiences acceleration. The peak acceleration is the largest acceleration recorded by a particular station during an earthquake.” Figure 14 indicates that seismicity is highest in the northeast corner of the state near the New Madrid fault (USGS, 2009B).



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

Figure 14: Peak Acceleration

By overlaying the seismicity map with a map of Arkansas counties, we estimated the seismicity level for each county. The seismicity was then categorized into three risk levels based on peak acceleration as expressed as a percentage of the acceleration due to gravity: low (0-19.9), medium (20-79.9), and high (≥80), as shown graphically in Figure 15. Counties with low, medium, or high risk levels were given a score of one, two, or three respectively.

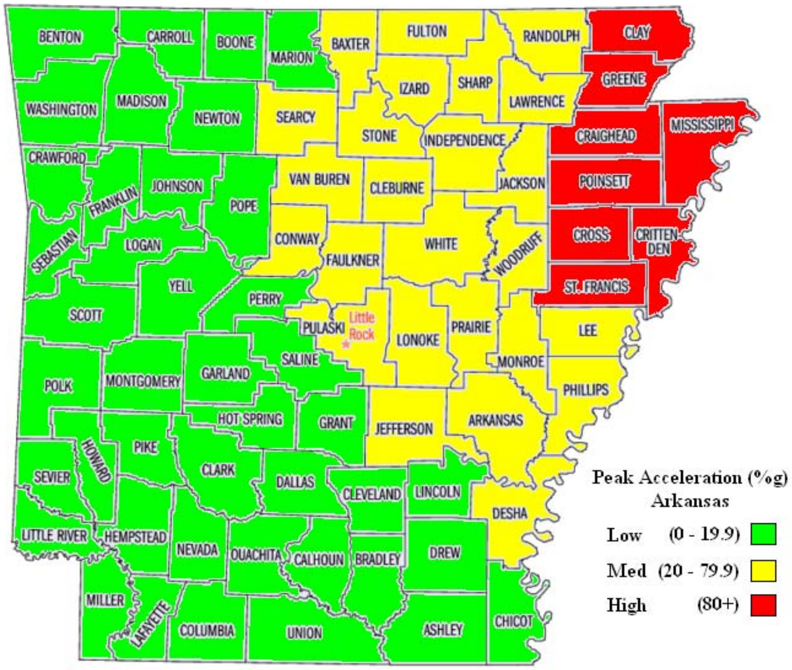


Figure 15: Risk of Earthquake

According to the Arkansas EOP (ADEM, 2007), "Every county in the State can be affected by flooding. Floods are extremely dangerous because they cause damage through inundation and soaking as well as the incredible force of moving water. High volumes of water can move heavy objects and undermine roads and bridges. Floods often occur without local precipitation as a result of precipitation upstream." FEMA provides a description for all major disasters that have occurred in each state. In order to determine the flood risk for each county in Arkansas, we looked at the major disaster descriptions for the state of Arkansas over the last ten years. For each disaster that included flooding in the description, we recorded which counties in Arkansas filed a declaration for that disaster. The number of declarations for each county in Arkansas can be found in Appendix VII (FEMA, 2009). Based on the total number of flood disaster declarations that each county made over the last ten years, the counties were categorized as having a low (1 – 2), medium

(3 – 4), or high (5 – 6) risk of flood. Counties with a low, medium, or high risk of flood were given a score of one, two, or three respectively. Note that the scale for this data was created using only the data for the state of Arkansas, where the maximum number of flood declarations for any single county was six over the last ten years. If this method for determining flood risk is applied to another state, the scale for categorizing flood risk by county may need to be adjusted. Figure 16 depicts the county-level flood risks graphically.

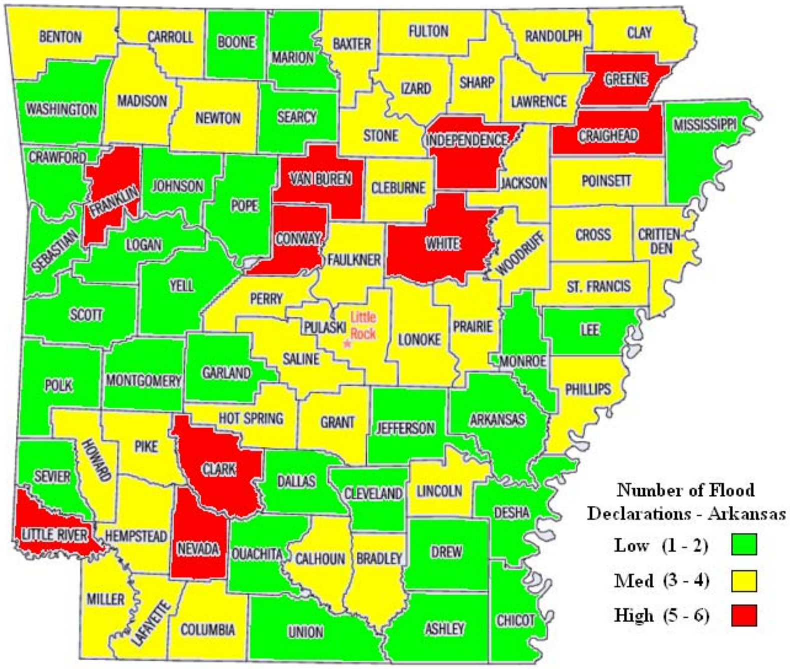


Figure 16: Risk of Flood

According to the Arkansas EOP (ADEM, 2007), "there is no sure way to predict future terrorism events. Since Arkansas is primarily rural, terrorists could very well gather materials, make plans and carry out those plans undetected. There are several locations in Arkansas that could be very attractive targets to a terrorist." In this case study, we assume that the two primary targets would be the Pine Bluff Arsenal, a munitions facility that stores and destroys chemical weapons, and Arkansas Nuclear One (ANO), a nuclear power plant located in Russellville. An attack on either of these two locations, however unlikely, would pose a huge threat to the surrounding areas. Using this information, we have assigned a low, medium, or high risk for terrorist attack to each county in Arkansas based on its proximity to one or both of these locations. The counties containing ANO and the Pine Bluff Arsenal and all adjacent counties were categorized as being at high risk for terrorist attack. Counties further away but still adjacent to a high risk county were categorized as having a medium risk for terrorist attack. All remaining counties were placed in the low risk category. A county categorized as low, medium, or high risk is given a score of one, two, or three respectively. This is depicted graphically in Figure 17. Note that this method of estimating risk for a terrorist attack only considers the potential targets for the state of Arkansas. The risks generated by any potential targets in bordering states were not taken into account.

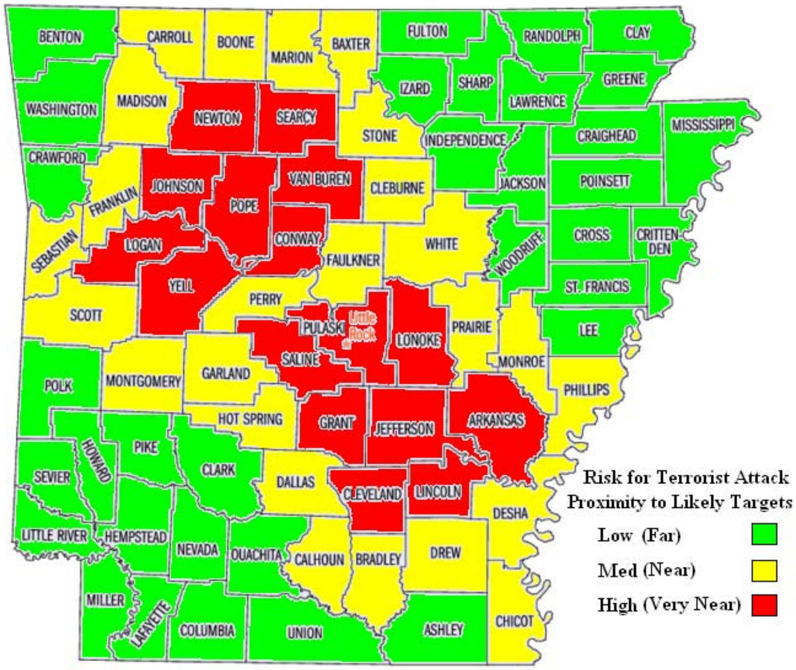


Figure 17: Risk of Terrorist Attack

After subfactor values for tornado, earthquake, flood risk, and terrorist attack were determined for each county, we calculated the overall risk of disaster by summing the scores of the four disasters for each county. A county with a score in the range 4-6, 7-9, or 10-12 was classified as having a low, medium, or high disaster risk respectively. A disaster risk of low, medium, or high was given a *Risk of Disaster* value of one, two, or three respectively. These values are depicted graphically in Figure 18.

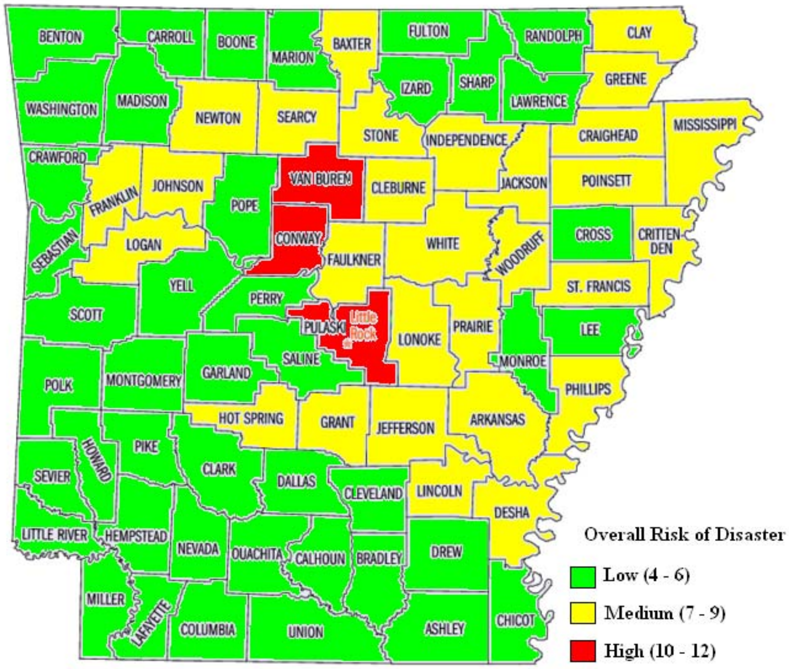


Figure 18: Overall Risk of Disaster

4.2.6 Limited Access to Medical Services

In order to measure Limited Access to Medical Services for Arkansas, we used the number of community hospital beds per 100,000 persons (U.S. Census Bureau, 2007). In year 2004, the average number of hospital beds per 100,000 persons nationwide was 317 per county. The counties with 0 hospital beds per 100,000 persons are considered to have a high potential of benefiting from a medical barge, counties with 1 to 317 (national average) to have medium potential, and counties with more than 317 to have low potential. Counties with a Low, Medium, and High potential are given scores one, two, or three respectively. The data can be found in the Appendix VIII. Figure 19 shows the counties of Arkansas classified as high, medium, or low according to their limited access to medical services.

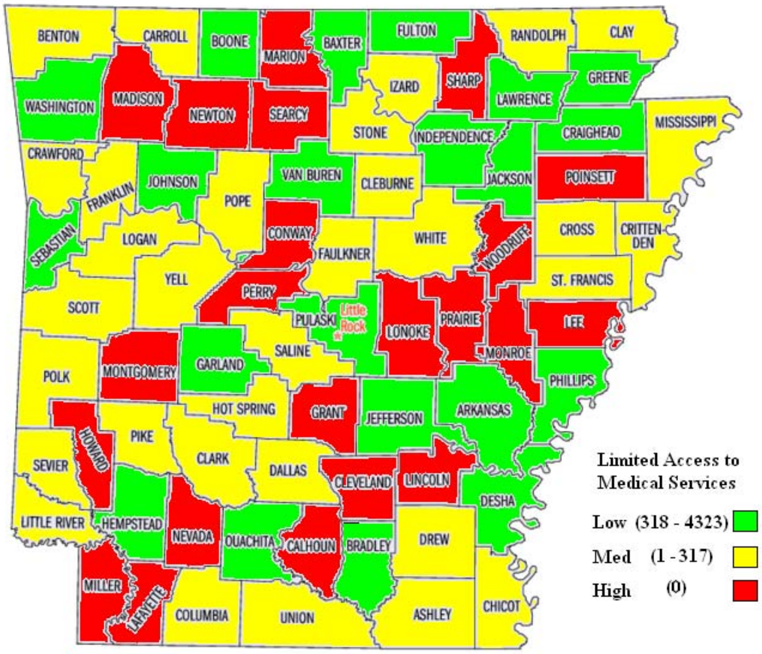


Figure 19: Limited Access to Medical Services

4.3 WEMS Index Calculation

After the six factor scores were determined for each county in Arkansas, the overall index value for each county was calculated using Equation 1.

$$WEMS\ Index\ Value = A(P + PD + V + R + M) \tag{1}$$

$$where\ A = Accessibility\ to\ Navigable\ Waterway\ score$$

$$P = Proximity\ to\ Barge\ Origin\ score$$

$$PD = Population\ Demands\ score$$

$$V = Social\ Vulnerability\ score$$

$$R = Risk\ of\ Disaster\ score$$

$$M = Limited\ Access\ to\ Medical\ Services$$

The counties with WEMS Index equal to 0 have no potential, the counties with WEMS Index of 5, 6, or 7 have low potential, the counties with WEMS Index of 8, 9, or 10 have medium potential, and the counties with WEMS Index of 11, 12, 13, 14, or 15 are have high potential to benefit from emergency response via inland waterways.

As an example, Jefferson County has a medium level of potential to benefit from inland waterway emergency medical services as indicated by its WEMS Index value of 12.

$$WEMS\ Index\ Value_{Jefferson\ County} = A(P + PD + V + R + M)$$

where A = 1, P = 3, PD = 3, V = 3, R = 2 and M = 1

$$WEMS\ Index\ Value_{Jefferson\ County} = 1(3 + 3 + 3 + 2 + 1)$$

$$WEMS\ Index\ Value_{Jefferson\ County} = 12$$

The factor values and WEMS Index for each county in Arkansas can be found in Appendix IX. Figure 19 graphically depicts the WEMS index value level to which each county in Arkansas could potentially benefit from inland waterway emergency medical response.

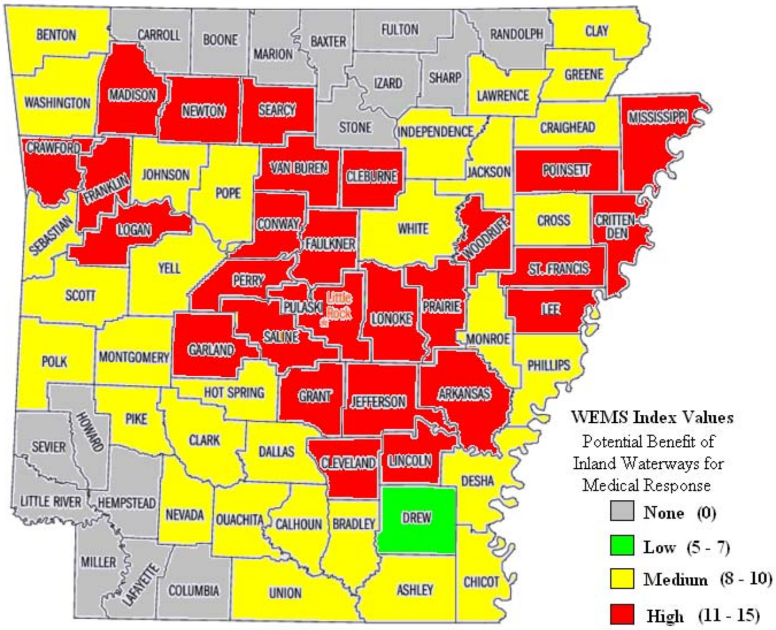


Figure 20: WEMS Index Values

One of the counties with the highest WEMS Index is Pulaski, which is located centrally in the state and is home to the state capital. Pulaski County has a high potential to benefit from inland waterway emergency medical services due to its high risk for disaster, large population, high SoVI value, and close proximity to a navigable inland waterway. There are a total of twenty seven counties with high WEMS Index values including Jefferson, Crittenden, and Van Buren.

There are sixteen counties in Arkansas that are more than a three hour drive from public ports on navigable inland waterways, making the use of those waterways infeasible for emergency medical response. These counties have a WEMS index of zero and, as can be expected, are located primarily in the southwest and north-central regions of the state away from the Arkansas and Mississippi Rivers. Only one county in Arkansas has a WEMS index less than eight. Thirty one counties have medium potential to benefit from inland waterway medical response, resulting in a total of fifty eight counties (77%) with at least medium potential to benefit from these services. In fact, all of the sixteen counties with no inland waterway access still show a medium or high need for waterway-based medical assistance based on the other WEMS factors. If private ports were taken into consideration, these counties could potentially have access to a navigable inland waterway.

5 Sensitivity Analysis

In order to determine the effect of each factor on WEMS Index, a sensitivity analysis was performed. In the baseline calculations of WEMS Index, the five factors discussed on Section 4 (Proximity to Barge Origin, Population Demands, Social Vulnerability, Risk of Disaster, and Limited Access to Medical Services) are considered to be of equally weighted importance (equal weights of one). The factor Accessibility to Navigable Inland Waterway is not considered in the sensitivity analysis since it only has the value of zero or one. The sensitivity analysis performed considers four scenarios:

- Scenario One – Slightly High (SH): one factor is weighed slightly higher (1.364) than the other four factors (0.909) in each case,
- Scenario Two – Slightly Low (SL): one factor is weighted slightly less weight (0.714) than the other four factors (1.071) in each case,
- Scenario Three – Very High (VH): one factor is weighted much higher (3.0) than the other four factors (0.5) in each case,
- Scenario Four – Very Low (LH): one factor is weighted much less (0.2) than the other four factors (1.2) in each case.

In the Scenario One cases, we consider that one of the factors has the weight equal to 1.5 times higher than the other four factors. The detailed sets of weights for each case are shown in Table 7. The results presented in Table 8 show the number of counties whose potential to benefit from inland waterways changed during the Scenario One sensitivity analysis and what the category changes were.

Table 7: Scenario One Weights of Factor

Factor	Proximity to Barge Origin(P)	Population Demand(PD)	Social Vulnerability(SV)	Risk of Disaster(RD)	Limited Access to Medical Services(M)
P-SH	1.364	0.909	0.909	0.909	0.909
PD-SH	0.909	1.364	0.909	0.909	0.909
SV-SH	0.909	0.909	1.364	0.909	0.909
RD-SH	0.909	0.909	0.909	1.364	0.909
M-SH	0.909	0.909	0.909	0.909	1.364

Table 8: Scenario One Sensitivity Analysis Results

Change	P-SH	PD-SH	SV-SH	RD-SH	M-SH
Medium to Low	0	3	3	2	2
High to Medium	4	11	9	15	10

In the Scenario Two cases, one of the factors is considered to have the weight equal to 1.5 times less than the other four factors. The detailed sets of weights for each case are shown in Table 9. The results presented in Table 10 show the number of counties whose potential to benefit from inland waterways changed during the Scenario One sensitivity analysis and what the category changes were. The results of Scenarios One and Two show that, with slight changes in the weights, only a few counties change their category status. This indicates that the results are pretty robust to slight variation in factor weights.

Table 9: Scenario Two Weights of Factors

Factor	Proximity to Barge Origin(P)	Population Demand(PD)	Social Vulnerability(SV)	Risk of Disaster(RD)	Limited Access to Medical Services(M)
P-SL	0.714	1.071	1.071	1.071	1.071
PD-SL	1.071	0.714	1.071	1.071	1.071
SV-SL	1.071	1.071	0.714	1.071	1.071
RD-SL	1.071	1.071	1.071	0.714	1.071
M-SL	1.071	1.071	1.071	1.071	0.714

Table 10: Scenario Two Sensitivity Analysis

Change	P-SL	PD-SL	SV-SL	RD-SL	M-SL
Medium to Low	4	1	1	2	2
High to Medium	12	5	7	1	6

In Scenarios Three and Four, the weight of a single factor is dramatically changed from its original weight of one. In the Scenario Three cases, one factor has a weight six times greater than the other four factors. The weights for Scenario Three and its results are presented in Tables 11 and 12 respectively.

Table 11: Scenario Three Weights of Factors

Factor	Proximity to Barge Origin(P)	Population Demand(PD)	Social Vulnerability(SV)	Risk of Disaster(RD)	Limited Access to Medical Services(M)
P-VH	3.0	0.5	0.5	0.5	0.5
PD-VH	0.5	3.0	0.5	0.5	0.5
SV-VH	0.5	0.5	3.0	0.5	0.5
RD-VH	0.5	0.5	0.5	3.0	0.5
M-VH	0.5	0.5	0.5	0.5	3.0

Table 12: Scenario Three Sensitivity Analysis Results

Change	P-VH	PD-VH	SV-VH	RD-VH	M-VH
Low to Medium	1	0	0	0	1
Medium to Low	0	13	11	22	13
Medium to High	20	4	10	0	4
High to Medium	4	11	12	17	12

In the Scenario Four cases, one factors has a weight six times less than the other four factors. The weights for Scenario Four and its results are presented in Tables 13 and 14 respectively.

Table 13: Scenario Four Weights of Factors

Factor	Proximity to Barge Origin(P)	Population Demand(PD)	Social Vulnerability(SV)	Risk of Disaster(RD)	Limited Access to Medical Services(M)
P-VL	0.2	1.2	1.2	1.2	1.2
PD-VL	1.2	0.2	1.2	1.2	1.2
SV-VL	1.2	1.2	0.2	1.2	1.2
RD-VL	1.2	1.2	1.2	0.2	1.2
M-VL	1.2	1.2	1.2	1.2	0.2

Table 14: Scenario Four Sensitivity Analysis Results

Change	P-VL	PD-VL	SV-VL	RD-VL	M-VL
Low to Medium	0	0	0	0	0
Medium to Low	13	1	6	2	4
Medium to High	0	4	2	10	4
High to Medium	12	5	7	1	6

The results of Scenarios Three and Four show that dramatic changes in the weights will result in a noticeable number of counties changing from high potential to benefit from inland waterways to having medium potential. In particular, a noticeable number of changes also happened from medium to low potential in addition to some changes in other categories. This shows that the overall category results do change if the weights on the factors change dramatically. Overall we conclude that the results are not sensitive to slight changes in WEMS factor weights, while the results will show high sensitivity if the weights change dramatically. The detailed results are available in Appendix X.

6 Conclusions and Future Work

6.1 Conclusions

Most EOPs assume that standard modes of transportation will be available for disaster response. Given that catastrophic events are by nature destructive, this assumption may need to be reconsidered. A violent tornado or a powerful earthquake may inhibit or destroy major roadways, bridges, and tunnels. Victims of a disaster may quickly overwhelm local medical facilities. Communities with access to navigable inland waterways should consider those waterways as a contingency or supplement to their current EOPs. The WEMS Index is a useful tool for emergency planners to gage the feasibility of using navigable inland waterways to provide emergency medical services to disaster victims.

The case study of Arkansas is a useful demonstration of the application of the WEMS index to a wide variety of communities. While most of the counties in Arkansas show at least some potential to benefit from waterway medical services, some counties still show a need but lack of inland waterway access. While information was limited and some general assumptions were made, local emergency planners are likely to be more knowledgeable about available resources and are encouraged to adjust the WEMS factors according to their specific community.

6.2 Future Work

This initial work in the feasibility of emergency medical response via inland waterways generated several additional research questions. For example, the optimal starting locations of medical barges could be investigated. Identifying strategic locations to dock the vessels could be useful for minimizing response time to key areas. This idea could be further explored to determine if the strategic locations should change based on the time of year or risk of events. For example, during tornado season, it may be prudent to dock a medical barge nearest to those counties at higher risk for tornado. Further research may even result in a policy for dispatching medical barges *prior* to an emergency. For example, if a large storm cell is moving into a certain part of the state, authorities could dispatch a barge to that location in anticipation of an emergency medical situation.

Further research will include determining which medical services could and should be offered by a medical response barge. Available funding and specifications of the barge may limit the number and type of emergency medical services that could be provided. For example, a barge with the capability to perform on site surgeries may be far more useful for certain types of disasters than a barge that is only equipped for first response. It may be useful to explore the layout, capacity, and potential capabilities of various barge configurations in order to identify the level of medical care that could be provided.

In another research area, it may prove valuable to explore the use of watercraft other than barges to provide emergency medical assistance. While the capacity may be significantly less than that of a barge, a smaller faster boat (or a fleet of boats) could respond to emergencies more quickly. This could potentially expand the list of emergencies for which inland waterway response would be viable.

The economic feasibility of emergency medical response via inland waterways is another area in which there is much potential for future research. Because all emergency operations plans are limited by a budget, estimating the costs of equipment, personnel, supplies, and daily operations of a medical barge would prove useful to emergency planners. In addition to providing valuable information as to which medical services could be offered, further exploration into this field may also help to identify a method for customizing an emergency medical barge to meet the needs of a certain community or communities.

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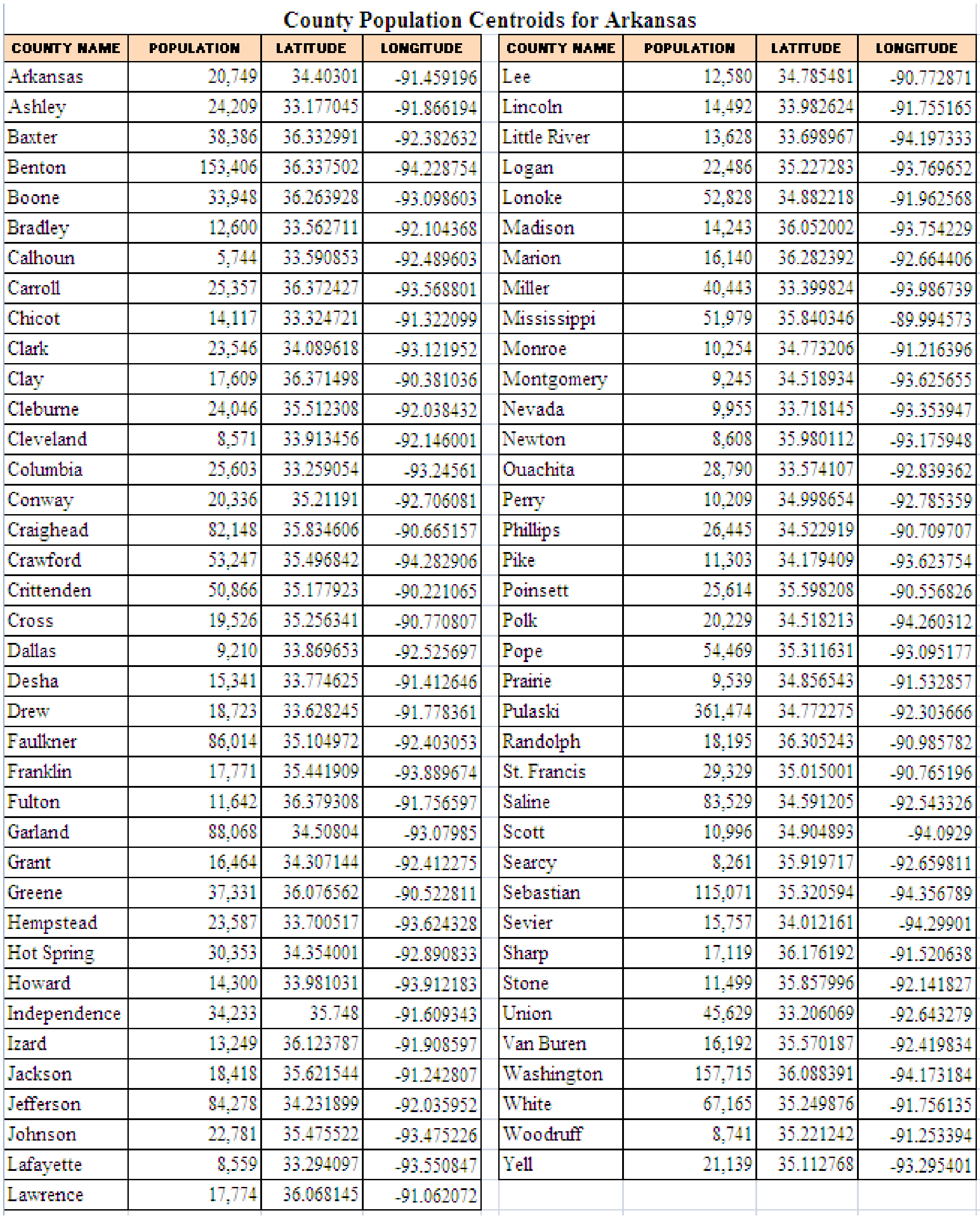
Appendix I: County Population Centroids for Arkansas



County Population Centroids for Arkansas

COUNTY NAME	POPULATION	LATITUDE	LONGITUDE
Arkansas	20,749	34.40301	-91.459196
Ashley	24,209	33.177045	-91.866194
Baxter	38,386	36.332991	-92.382632
Benton	153,406	36.337502	-94.228754
Boone	33,948	36.263928	-93.098603
Bradley	12,600	33.562711	-92.104368
Calhoun	5,744	33.590853	-92.489603
Carroll	25,357	36.372427	-93.568801
Chicot	14,117	33.324721	-91.322099
Clark	23,546	34.089618	-93.121952
Clay	17,609	36.371498	-90.381036
Cleburne	24,046	35.512308	-92.038432
Cleveland	8,571	33.913456	-92.146001
Columbia	25,603	33.259054	-93.24561
Conway	20,336	35.21191	-92.706081
Craighead	82,148	35.834606	-90.665157
Crawford	53,247	35.496842	-94.282906
Crittenden	50,866	35.177923	-90.221065
Cross	19,526	35.256341	-90.770807
Dallas	9,210	33.869653	-92.525697
Desha	15,341	33.774625	-91.412646
Drew	18,723	33.628245	-91.778361
Faulkner	86,014	35.104972	-92.403053
Franklin	17,771	35.441909	-93.889674
Fulton	11,642	36.379308	-91.756597
Garland	88,068	34.50804	-93.07985
Grant	16,464	34.307144	-92.412275
Greene	37,331	36.076562	-90.522811
Hempstead	23,587	33.700517	-93.624328
Hot Spring	30,353	34.354001	-92.890833
Howard	14,300	33.981031	-93.912183
Independence	34,233	35.748	-91.609343
Izard	13,249	36.123787	-91.908597
Jackson	18,418	35.621544	-91.242807
Jefferson	84,278	34.231899	-92.035952
Johnson	22,781	35.475522	-93.475226
Lafayette	8,559	33.294097	-93.550847
Lawrence	17,774	36.068145	-91.062072
Lee	12,580	34.785481	-90.772871
Lincoln	14,492	33.982624	-91.755165
Little River	13,628	33.698967	-94.197333
Logan	22,486	35.227283	-93.769652
Lonoke	52,828	34.882218	-91.962568
Madison	14,243	36.052002	-93.754229
Marion	16,140	36.282392	-92.664406
Miller	40,443	33.399824	-93.986739
Mississippi	51,979	35.840346	-89.994573
Monroe	10,254	34.773206	-91.216396
Montgomery	9,245	34.518934	-93.625655
Nevada	9,955	33.718145	-93.353947
Newton	8,608	35.980112	-93.175948
Ouachita	28,790	33.574107	-92.839362
Perry	10,209	34.998654	-92.785359
Phillips	26,445	34.522919	-90.709707
Pike	11,303	34.179409	-93.623754
Poinsett	25,614	35.598208	-90.556826
Polk	20,229	34.518213	-94.260312
Pope	54,469	35.311631	-93.095177
Prairie	9,539	34.856543	-91.532857
Pulaski	361,474	34.772275	-92.303666
Randolph	18,195	36.305243	-90.985782
St. Francis	29,329	35.015001	-90.765196
Saline	83,529	34.591205	-92.543326
Scott	10,996	34.904893	-94.0929
Searcy	8,261	35.919717	-92.659811
Sebastian	115,071	35.320594	-94.356789
Sevier	15,757	34.012161	-94.29901
Sharp	17,119	36.176192	-91.520638
Stone	11,499	35.857996	-92.141827
Union	45,629	33.206069	-92.643279
Van Buren	16,192	35.570187	-92.419834
Washington	157,715	36.088391	-94.173184
White	67,165	35.249876	-91.756135
Woodruff	8,741	35.221242	-91.253394
Yell	21,139	35.112768	-93.295401

Appendix II: Travel Times between County and Nearest Port

County	Port	Distance (miles)	Travel Time @ 35mph (hours)	Accessible?
Arkansas	Pine Bluff	47	1.3	1
Ashley	Yellow bend	53	1.5	1
Baxter	Little Rock	158	4.5	0
Benton	Ft. Smith	80.4	2.3	1
Boone	Ft. Smith	138	3.9	0
Bradley	Pine Bluff	51.5	1.5	1
Calhoun	Pine Bluff	58.7	1.7	1
Carroll	Ft. Smith	127	3.6	0
Chicot	Yellow bend	25.7	0.7	1
Clark	Little Rock	69.7	2.0	1
Clay	Osceola	90.7	2.6	1
Cleburne	Little Rock	75.9	2.2	1
Cleveland	Pine Bluff	27.7	0.8	1
Columbia	Pine Bluff	109	3.1	0
Conway	Lake Dardanelle	50.1	1.4	1
Craighead	Osceola	70.9	2.0	1
Crawford	Ft. Smith	12.2	0.3	1
Crittenden	West Memphis	4.6	0.1	1
Cross	West Memphis	40.6	1.2	1
Dallas	Pine Bluff	47.4	1.4	1
Desha	Yellow bend	30.8	0.9	1
Drew	Yellow bend	41	1.2	1
Faulkner	Little Rock	33.3	1.0	1
Franklin	Lake Dardanelle	42.7	1.2	1
Fulton	Little Rock	156	4.5	0
Garland	Little Rock	55.8	1.6	1
Grant	Pine Bluff	26	0.7	1
Greene	Osceola	55.7	1.6	1
Hempstead	Little Rock	111	3.2	0
Hot Spring	Little Rock	46.5	1.3	1
Howard	Little Rock	133	3.8	0
Independence	Little Rock	98.2	2.8	1
Izard	Little Rock	132	3.8	0
Jackson	West Memphis	83.4	2.4	1
Jefferson	Pine Bluff	2.6	0.1	1
Johnson	Lake Dardanelle	14.9	0.4	1
Lafayette	Pine Bluff	127	3.6	0

Appendix II (cont): Travel Times between County and Nearest Port

County	Port	Distance (miles)	Travel Time @ 35mph (hours)	Accessible?
Lawrence	West Memphis	93	2.7	1
Lee	Helena	26.6	0.8	1
Lincoln	Pine Bluff	29.3	0.8	1
Little River	Little Rock	161	4.6	0
Logan	Ft. Smith	46.1	1.3	1
Lonoke	Little Rock	26.9	0.8	1
Madison	Ft. Smith	95.2	2.7	1
Marion	Little Rock	159	4.5	0
Miller	Little Rock	144	4.1	0
Mississippi	Osceola	15.4	0.4	1
Monroe	Helena	44.6	1.3	1
Montgomery	Little Rock	92.1	2.6	1
Nevada	Little Rock	105	3.0	1
Newton	Lake Dardanelle	80.7	2.3	1
Ouachita	Pine Bluff	72.4	2.1	1
Perry	Little Rock	46.3	1.3	1
Phillips	Helena	9.9	0.3	1
Pike	Little Rock	101	2.9	1
Poinsett	West Memphis	42.8	1.2	1
Polk	Ft. Smith	89.3	2.6	1
Pope	Lake Dardanelle	23.1	0.7	1
Prairie	Little Rock	49	1.4	1
Pulaski	Little Rock	4.6	0.1	1
Randolph	West Memphis	106	3.0	0
St. Francis	West Memphis	36.3	1.0	1
Saline	Little Rock	21.1	0.6	1
Scott	Ft. Smith	45.8	1.3	1
Searcy	Little Rock	99.8	2.9	1
Sebastian	Ft. Smith	7.2	0.2	1
Sevier	Ft. Smith	131	3.7	0
Sharp	Little Rock	134	3.8	0
Stone	Little Rock	107	3.1	0
Union	Pine Bluff	88.8	2.5	1
Van Buren	Little Rock	69.8	2.0	1
Washington	Ft. Smith	60.4	1.7	1
White	Little Rock	52.1	1.5	1
Woodruff	West Memphis	71.2	2.0	1
Yell	Lake Dardanelle	40.1	1.1	1

Appendix III: Travel Time between Arkansas Public Ports and Lake Dardanelle

Port	River	River Mile Marker	Distance to Lake Dardanelle (river miles)	Barge Travel Time (days)	WEMS Score
Lake Dardanelle	Arkansas	208	0	0.0	3
Little Rock	Arkansas	112.8	95.2	0.8	3
Fort Smith	Arkansas	308.7	100.7	0.9	3
Pine Bluff	Arkansas	71.2	136.8	1.2	3
Yellow Bend	Mississippi	554.1	252.9	2.2	2
Helena	Mississippi	652	261	2.3	2
West Memphis	Mississippi	727.3	336.3	2.9	2
Osceola	Mississippi	785.5	394.5	3.4	2

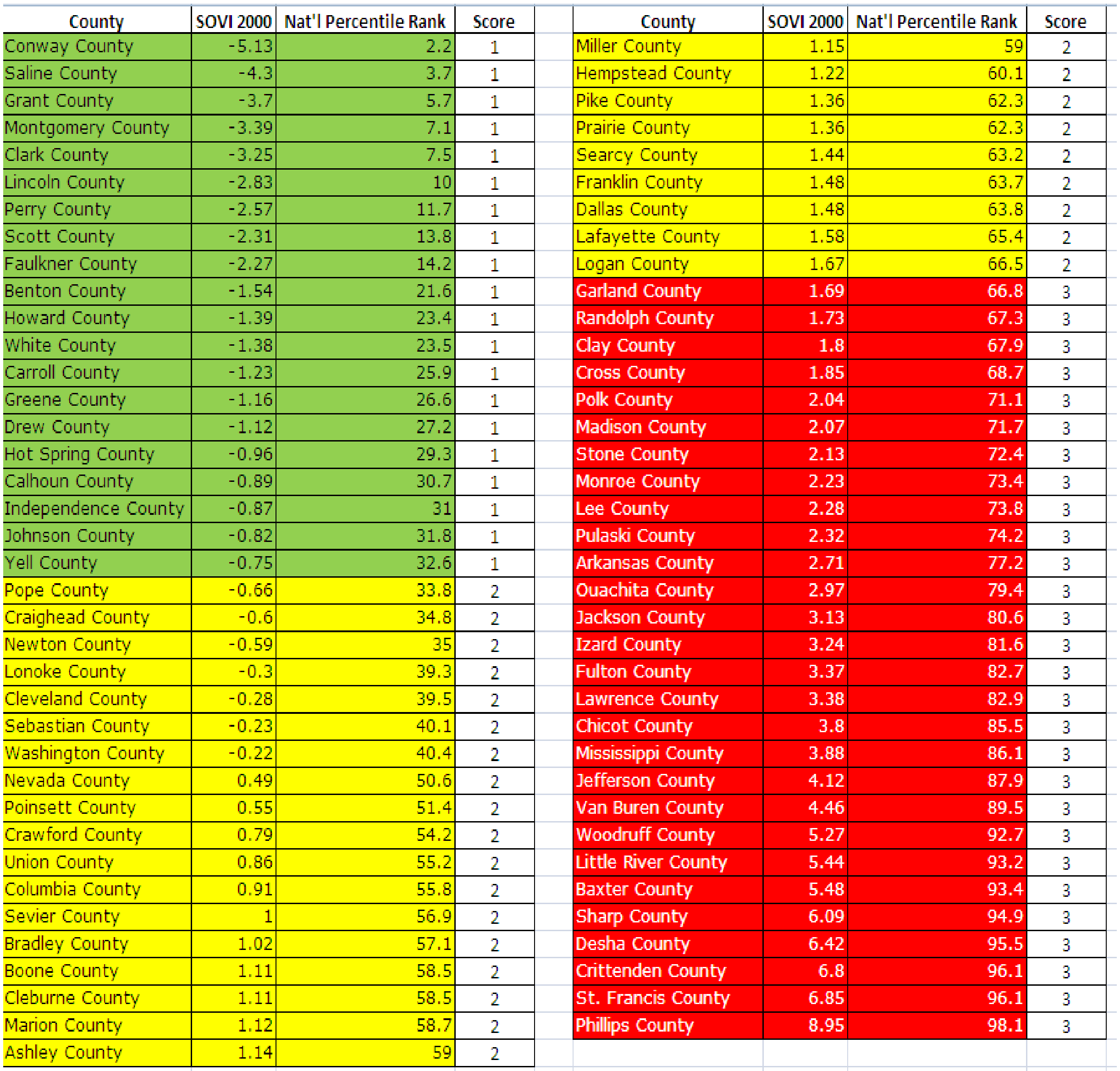
Appendix IV: 2003 Rural-Urban Continuum Codes for Counties in Arkansas

State	County Name	2003 Rural-urban Continuum Code	2000 Population	Percent of workers in nonmetro counties commuting to central counties of adjacent metro areas	Score
AR	Calhoun County	9	5,744	1.8	1
AR	Fulton County	9	11,642	0.0	1
AR	Izard County	9	13,249	0.0	1
AR	Marion County	9	16,140	0.0	1
AR	Newton County	9	8,608	1.6	1
AR	Pike County	9	11,303	0.0	1
AR	Searcy County	9	8,261	0.0	1
AR	Stone County	9	11,499	0.0	1
AR	Woodruff County	9	8,741	0.0	1
AR	Lafayette County	8	8,559	8.5	1
AR	Montgomery County	8	9,245	12.4	1
AR	Prairie County	8	9,539	21.7	1
AR	Van Buren County	8	16,192	20.8	1
AR	Ashley County	7	24,209	0.3	1
AR	Baxter County	7	38,386	0.0	1
AR	Boone County	7	33,948	0.0	1
AR	Chicot County	7	14,117	0.0	1
AR	Clark County	7	23,546	0.0	1
AR	Clay County	7	17,609	0.0	1
AR	Columbia County	7	25,603	0.0	1
AR	Drew County	7	18,723	1.9	1
AR	Howard County	7	14,300	0.0	1
AR	Independence County	7	34,233	0.0	1
AR	Monroe County	7	10,254	0.0	1
AR	Nevada County	7	9,955	0.0	1
AR	Ouachita County	7	28,790	0.0	1
AR	Phillips County	7	26,445	1.3	1
AR	Polk County	7	20,229	0.2	1
AR	Randolph County	7	18,195	0.0	1
AR	Sevier County	7	15,757	0.0	1
AR	Sharp County	7	17,119	0.0	1
AR	Arkansas County	6	20,749	4.4	2
AR	Bradley County	6	12,600	2.6	2
AR	Carroll County	6	25,357	3.4	2
AR	Cleburne County	6	24,046	11.4	2
AR	Conway County	6	20,336	30.5	2
AR	Cross County	6	19,526	13.5	2
AR	Dallas County	6	9,210	2.7	2
AR	Desha County	6	15,341	2.8	2

Appendix IV (cont): 2003 Rural-Urban Continuum Codes for Counties in Arkansas

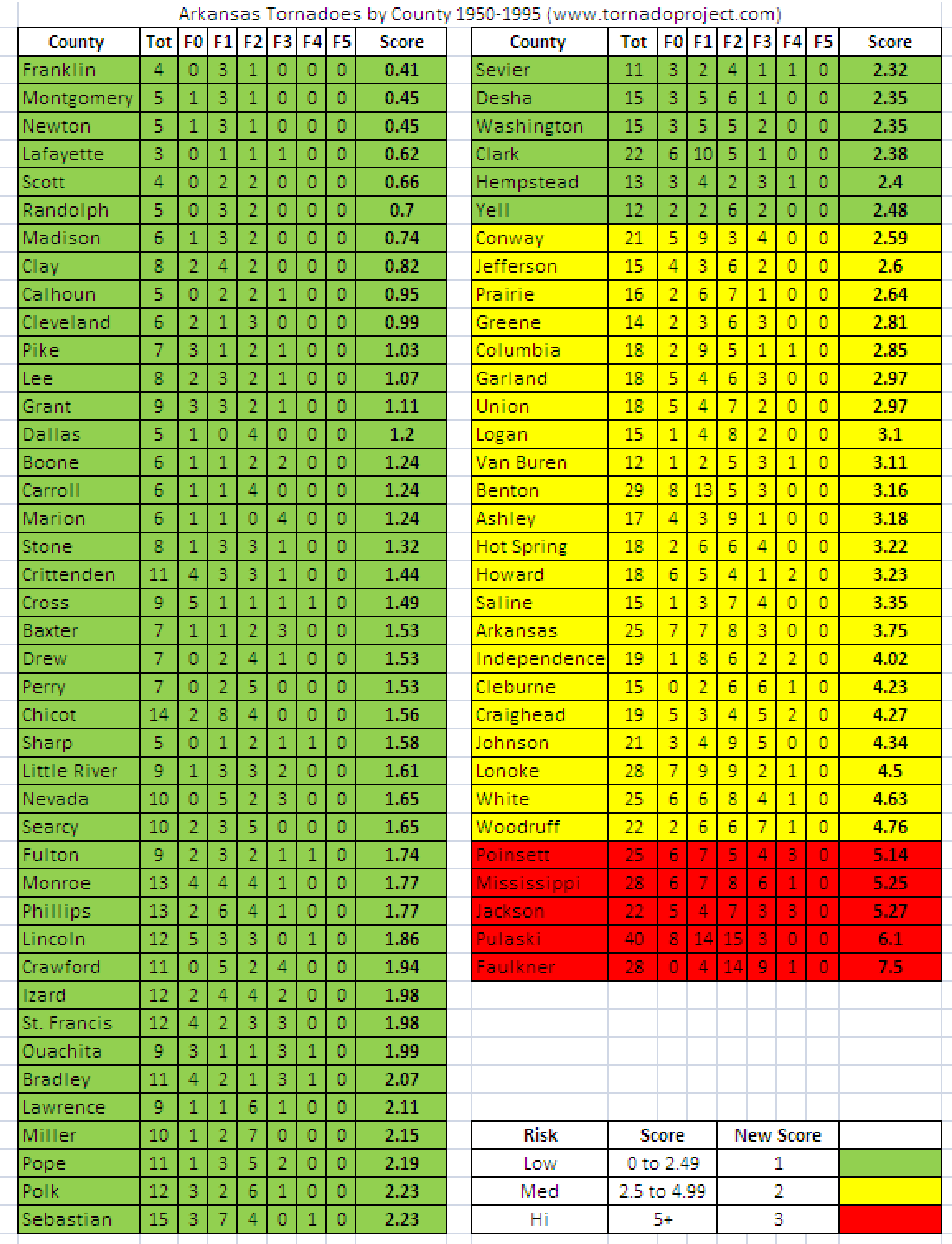
State	County Name	2003 Rural-urban Continuum Code	2000 Population	Percent of workers in nonmetro counties commuting to central counties of adjacent metro areas	Score
AR	Greene County	6	37,331	11.9	2
AR	Hempstead County	6	23,587	3.4	2
AR	Hot Spring County	6	30,353	35.5	2
AR	Jackson County	6	18,418	4.7	2
AR	Johnson County	6	22,781	2.3	2
AR	Lawrence County	6	17,774	15.8	2
AR	Lee County	6	12,580	4.8	2
AR	Little River County	6	13,628	22.3	2
AR	Logan County	6	22,486	13.2	2
AR	Scott County	6	10,996	14.8	2
AR	St. Francis County	6	29,329	13.9	2
AR	Yell County	6	21,139	2.5	2
AR	Pope County	5	54,469	0.0	2
AR	Union County	5	45,629	0.2	2
AR	Mississippi County	4	51,979	5.3	2
AR	White County	4	67,165	17.4	2
AR	Cleveland County	3	8,571	0.0	3
AR	Craighead County	3	82,148	0.0	3
AR	Garland County	3	88,068	0.0	3
AR	Jefferson County	3	84,278	0.0	3
AR	Lincoln County	3	14,492	0.0	3
AR	Miller County	3	40,443	0.0	3
AR	Poinsett County	3	25,614	0.0	3
AR	Benton County	2	153,406	0.0	3
AR	Crawford County	2	53,247	0.0	3
AR	Faulkner County	2	86,014	0.0	3
AR	Franklin County	2	17,771	0.0	3
AR	Grant County	2	16,464	0.0	3
AR	Lonoke County	2	52,828	0.0	3
AR	Madison County	2	14,243	0.0	3
AR	Perry County	2	10,209	0.0	3
AR	Pulaski County	2	361,474	0.0	3
AR	Saline County	2	83,529	0.0	3
AR	Sebastian County	2	115,071	0.0	3
AR	Washington County	2	157,715	0.0	3
AR	Crittenden County	1	50,866	0.0	3

Appendix V: SoVI Values for Counties in Arkansas



County	SOVI 2000	Nat'l Percentile Rank	Score
Conway County	-5.13	2.2	1
Saline County	-4.3	3.7	1
Grant County	-3.7	5.7	1
Montgomery County	-3.39	7.1	1
Clark County	-3.25	7.5	1
Lincoln County	-2.83	10	1
Perry County	-2.57	11.7	1
Scott County	-2.31	13.8	1
Faulkner County	-2.27	14.2	1
Benton County	-1.54	21.6	1
Howard County	-1.39	23.4	1
White County	-1.38	23.5	1
Carroll County	-1.23	25.9	1
Greene County	-1.16	26.6	1
Drew County	-1.12	27.2	1
Hot Spring County	-0.96	29.3	1
Calhoun County	-0.89	30.7	1
Independence County	-0.87	31	1
Johnson County	-0.82	31.8	1
Yell County	-0.75	32.6	1
Pope County	-0.66	33.8	2
Craighead County	-0.6	34.8	2
Newton County	-0.59	35	2
Lonoke County	-0.3	39.3	2
Cleveland County	-0.28	39.5	2
Sebastian County	-0.23	40.1	2
Washington County	-0.22	40.4	2
Nevada County	0.49	50.6	2
Poinsett County	0.55	51.4	2
Crawford County	0.79	54.2	2
Union County	0.86	55.2	2
Columbia County	0.91	55.8	2
Sevier County	1	56.9	2
Bradley County	1.02	57.1	2
Boone County	1.11	58.5	2
Cleburne County	1.11	58.5	2
Marion County	1.12	58.7	2
Ashley County	1.14	59	2
Miller County	1.15	59	2
Hempstead County	1.22	60.1	2
Pike County	1.36	62.3	2
Prairie County	1.36	62.3	2
Searcy County	1.44	63.2	2
Franklin County	1.48	63.7	2
Dallas County	1.48	63.8	2
Lafayette County	1.58	65.4	2
Logan County	1.67	66.5	2
Garland County	1.69	66.8	3
Randolph County	1.73	67.3	3
Clay County	1.8	67.9	3
Cross County	1.85	68.7	3
Polk County	2.04	71.1	3
Madison County	2.07	71.7	3
Stone County	2.13	72.4	3
Monroe County	2.23	73.4	3
Lee County	2.28	73.8	3
Pulaski County	2.32	74.2	3
Arkansas County	2.71	77.2	3
Ouachita County	2.97	79.4	3
Jackson County	3.13	80.6	3
Izard County	3.24	81.6	3
Fulton County	3.37	82.7	3
Lawrence County	3.38	82.9	3
Chicot County	3.8	85.5	3
Mississippi County	3.88	86.1	3
Jefferson County	4.12	87.9	3
Van Buren County	4.46	89.5	3
Woodruff County	5.27	92.7	3
Little River County	5.44	93.2	3
Baxter County	5.48	93.4	3
Sharp County	6.09	94.9	3
Desha County	6.42	95.5	3
Crittenden County	6.8	96.1	3
St. Francis County	6.85	96.1	3
Phillips County	8.95	98.1	3

Appendix VI: Arkansas Tornadoes by County 1950-1995

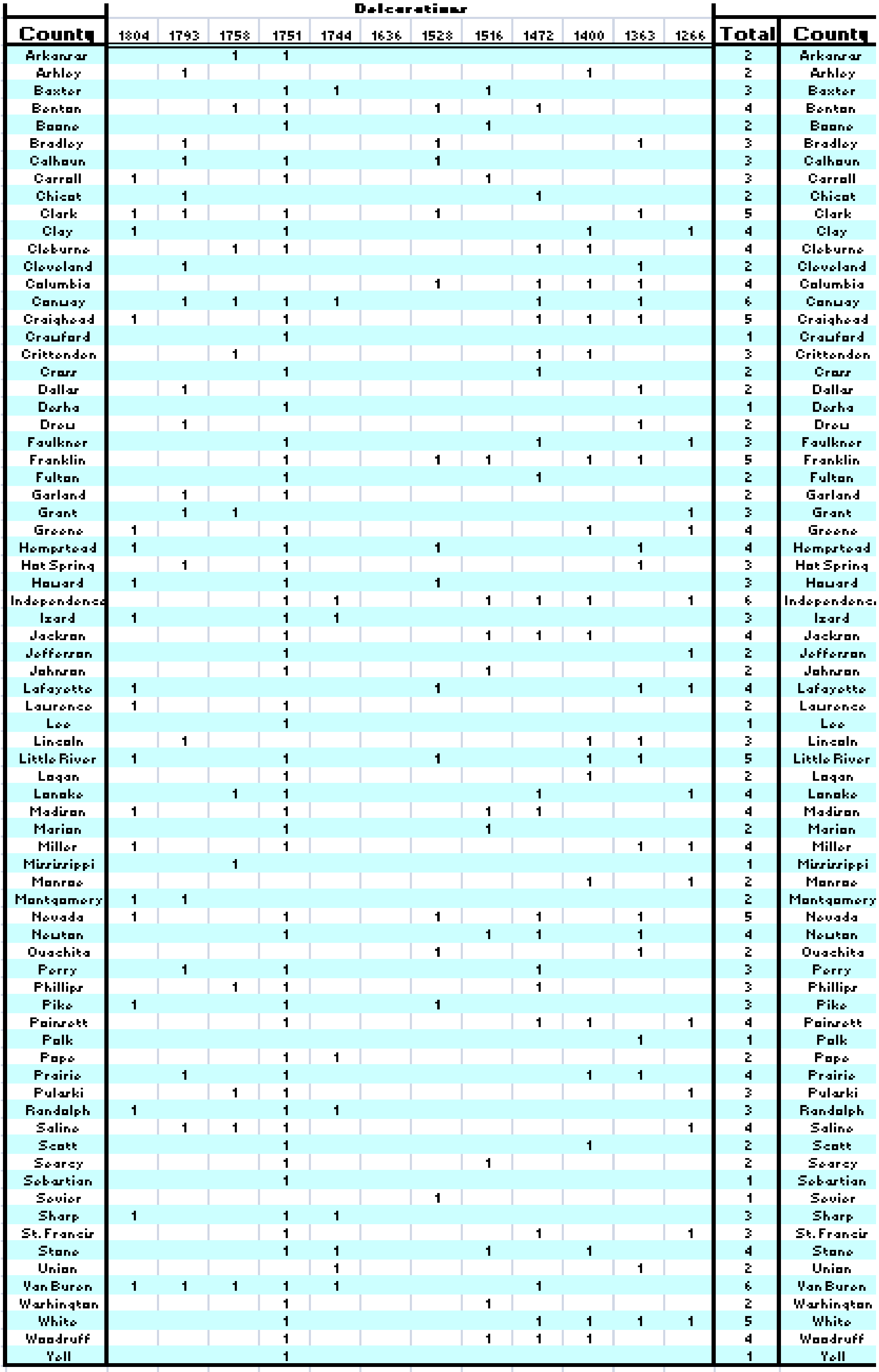


Arkansas Tornadoes by County 1950-1995 (www.tornadoproject.com)

County	Tot	F0	F1	F2	F3	F4	F5	Score
Franklin	4	0	3	1	0	0	0	0.41
Montgomery	5	1	3	1	0	0	0	0.45
Newton	5	1	3	1	0	0	0	0.45
Lafayette	3	0	1	1	1	0	0	0.62
Scott	4	0	2	2	0	0	0	0.66
Randolph	5	0	3	2	0	0	0	0.7
Madison	6	1	3	2	0	0	0	0.74
Clay	8	2	4	2	0	0	0	0.82
Calhoun	5	0	2	2	1	0	0	0.95
Cleveland	6	2	1	3	0	0	0	0.99
Pike	7	3	1	2	1	0	0	1.03
Lee	8	2	3	2	1	0	0	1.07
Grant	9	3	3	2	1	0	0	1.11
Dallas	5	1	0	4	0	0	0	1.2
Boone	6	1	1	2	2	0	0	1.24
Carroll	6	1	1	4	0	0	0	1.24
Marion	6	1	1	0	4	0	0	1.24
Stone	8	1	3	3	1	0	0	1.32
Crittenden	11	4	3	3	1	0	0	1.44
Cross	9	5	1	1	1	1	0	1.49
Baxter	7	1	1	2	3	0	0	1.53
Drew	7	0	2	4	1	0	0	1.53
Perry	7	0	2	5	0	0	0	1.53
Chicot	14	2	8	4	0	0	0	1.56
Sharp	5	0	1	2	1	1	0	1.58
Little River	9	1	3	3	2	0	0	1.61
Nevada	10	0	5	2	3	0	0	1.65
Searcy	10	2	3	5	0	0	0	1.65
Fulton	9	2	3	2	1	1	0	1.74
Monroe	13	4	4	4	1	0	0	1.77
Phillips	13	2	6	4	1	0	0	1.77
Lincoln	12	5	3	3	0	1	0	1.86
Crawford	11	0	5	2	4	0	0	1.94
Izard	12	2	4	4	2	0	0	1.98
St. Francis	12	4	2	3	3	0	0	1.98
Ouachita	9	3	1	1	3	1	0	1.99
Bradley	11	4	2	1	3	1	0	2.07
Lawrence	9	1	1	6	1	0	0	2.11
Miller	10	1	2	7	0	0	0	2.15
Pope	11	1	3	5	2	0	0	2.19
Polk	12	3	2	6	1	0	0	2.23
Sebastian	15	3	7	4	0	1	0	2.23
Sevier	11	3	2	4	1	1	0	2.32
Desha	15	3	5	6	1	0	0	2.35
Washington	15	3	5	5	2	0	0	2.35
Clark	22	6	10	5	1	0	0	2.38
Hempstead	13	3	4	2	3	1	0	2.4
Yell	12	2	2	6	2	0	0	2.48
Conway	21	5	9	3	4	0	0	2.59
Jefferson	15	4	3	6	2	0	0	2.6
Prairie	16	2	6	7	1	0	0	2.64
Greene	14	2	3	6	3	0	0	2.81
Columbia	18	2	9	5	1	1	0	2.85
Garland	18	5	4	6	3	0	0	2.97
Union	18	5	4	7	2	0	0	2.97
Logan	15	1	4	8	2	0	0	3.1
Van Buren	12	1	2	5	3	1	0	3.11
Benton	29	8	13	5	3	0	0	3.16
Ashley	17	4	3	9	1	0	0	3.18
Hot Spring	18	2	6	6	4	0	0	3.22
Howard	18	6	5	4	1	2	0	3.23
Saline	15	1	3	7	4	0	0	3.35
Arkansas	25	7	7	8	3	0	0	3.75
Independence	19	1	8	6	2	2	0	4.02
Cleburne	15	0	2	6	6	1	0	4.23
Craighead	19	5	3	4	5	2	0	4.27
Johnson	21	3	4	9	5	0	0	4.34
Lonoke	28	7	9	9	2	1	0	4.5
White	25	6	6	8	4	1	0	4.63
Woodruff	22	2	6	6	7	1	0	4.76
Poinsett	25	6	7	5	4	3	0	5.14
Mississippi	28	6	7	8	6	1	0	5.25
Jackson	22	5	4	7	3	3	0	5.27
Pulaski	40	8	14	15	3	0	0	6.1
Faulkner	28	0	4	14	9	1	0	7.5

Risk	Score	New Score	
Low	0 to 2.49	1	🟩
Med	2.5 to 4.99	2	🟨
Hi	5+	3	🟥

Appendix VII: Flood Declarations for Counties of Arkansas

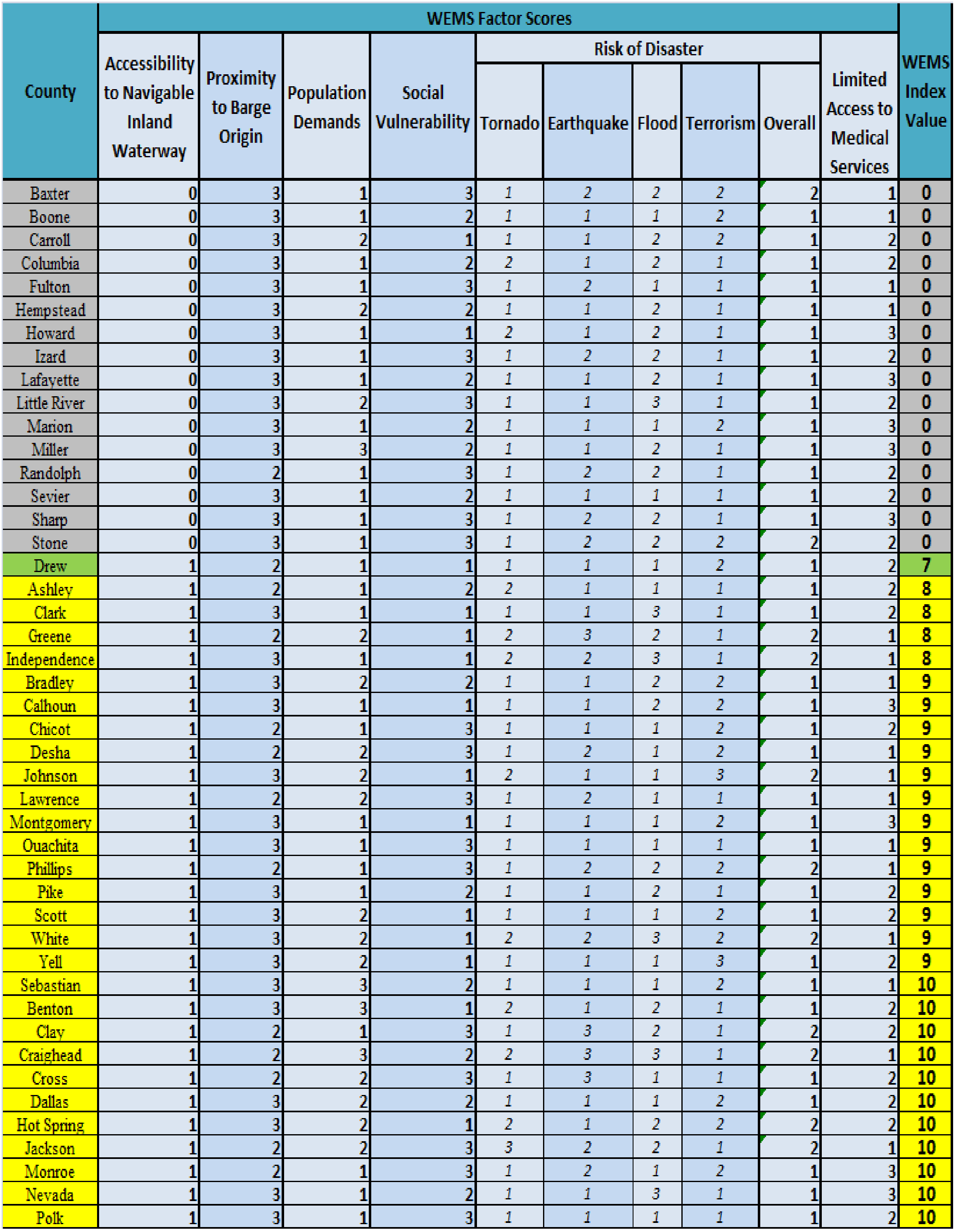


County	Delcarations												Total	County
	1804	1793	1758	1751	1744	1636	1528	1516	1472	1400	1363	1266		
Arkansas			1	1									2	Arkansas
Ashley		1								1			2	Ashley
Baxter				1	1			1					3	Baxter
Benton			1	1			1		1				4	Benton
Boone				1				1					2	Boone
Bradley		1					1				1		3	Bradley
Calhoun		1		1			1						3	Calhoun
Carroll	1			1				1					3	Carroll
Chicot		1							1				2	Chicot
Clark	1	1		1			1				1		5	Clark
Clay	1			1						1		1	4	Clay
Cleburne			1	1					1	1			4	Cleburne
Cleveland		1									1		2	Cleveland
Columbia							1		1	1	1		4	Columbia
Conway		1	1	1	1				1		1		6	Conway
Craighead	1			1					1	1	1		5	Craighead
Crawford				1									1	Crawford
Crittenden			1						1	1			3	Crittenden
Cross				1					1				2	Cross
Dallas		1									1		2	Dallas
Desha				1									1	Desha
Drew		1									1		2	Drew
Faulkner				1					1			1	3	Faulkner
Franklin				1			1	1		1	1		5	Franklin
Fulton				1					1				2	Fulton
Garland		1		1									2	Garland
Grant		1	1									1	3	Grant
Greene	1			1						1		1	4	Greene
Hempstead	1			1			1				1		4	Hempstead
Hot Spring		1		1							1		3	Hot Spring
Howard	1			1			1						3	Howard
Independence				1	1			1	1	1		1	6	Independence
Izard	1			1	1								3	Izard
Jackson				1				1	1	1			4	Jackson
Jefferson				1								1	2	Jefferson
Johnson				1				1					2	Johnson
Lafayette	1						1				1	1	4	Lafayette
Lawrence	1			1									2	Lawrence
Lee				1									1	Lee
Lincoln		1								1	1		3	Lincoln
Little River	1			1			1			1	1		5	Little River
Logan				1						1			2	Logan
Lonoke			1	1					1			1	4	Lonoke
Madison	1			1				1	1				4	Madison
Marion				1				1					2	Marion
Miller	1			1							1	1	4	Miller
Mississippi			1										1	Mississippi
Monroe										1		1	2	Monroe
Montgomery	1	1											2	Montgomery
Nevada	1			1			1		1		1		5	Nevada
Newton				1				1	1		1		4	Newton
Ouachita							1				1		2	Ouachita
Perry		1		1					1				3	Perry
Phillips			1	1					1				3	Phillips
Pike	1			1			1						3	Pike
Poinsett				1					1	1		1	4	Poinsett
Polk											1		1	Polk
Pope				1	1								2	Pope
Prairie		1		1						1	1		4	Prairie
Pulaski			1	1								1	3	Pulaski
Randolph	1			1	1								3	Randolph
Saline		1	1	1								1	4	Saline
Scott				1						1			2	Scott
Searcy				1				1					2	Searcy
Sebastian				1									1	Sebastian
Sevier							1						1	Sevier
Sharp	1			1	1								3	Sharp
St. Francis				1					1			1	3	St. Francis
Stone				1	1			1		1			4	Stone
Union					1						1		2	Union
Van Buren	1	1	1	1	1				1				6	Van Buren
Washington				1				1					2	Washington
White				1					1	1	1	1	5	White
Woodruff				1				1	1	1			4	Woodruff
Yell				1									1	Yell

Appendix VIII: Number of Community Hospital Beds

County	Community Hospitals, 2004, Beds, Rate per 100,000 persons	Scores
Lawrence	1232	1
Van Buren	1164	1
Jackson	956	1
Pulaski	686	1
Baxter	668	1
Sebastian	638	1
Arkansas	607	1
Craighead	555	1
Desha	516	1
Garland	509	1
Independence	503	1
Jefferson	454	1
White	451	1
Hempstead	444	1
Phillips	411	1
Bradley	398	1
Ouachita	359	1
Boone	355	1
Fulton	337	1
Johnson	337	1
Washington	336	1
Greene	332	1
Union	314	2
Drew	312	2
Yell	291	2
Pike	291	2
Polk	289	2
Dallas	288	2
Mississippi	281	2
Pope	275	2
Sevier	273	2
Chicot	265	2
Hot Spring	262	2
Columbia	249	2
St. Francis	249	2
Randolph	244	2
Crittenden	235	2
Carroll	226	2
Scott	218	2
Stone	215	2
Clay	209	2
Little River	189	2
Izard	188	2
Benton	185	2
Crawford	182	2
Logan	179	2
Faulkner	157	2
Ashley	153	2
Franklin	139	2
Saline	119	2
Clark	108	2
Cross	79	2
Cleburne	72	2
Calhoun	0	3
Cleveland	0	3
Conway	0	3
Grant	0	3
Howard	0	3
Lafayette	0	3
Lee	0	3
Lincoln	0	3
Lonoke	0	3
Madison	0	3
Marion	0	3
Miller	0	3
Monroe	0	3
Montgomery	0	3
Nevada	0	3
Newton	0	3
Perry	0	3
Poinsett	0	3
Prairie	0	3
Searcy	0	3
Sharp	0	3
Woodruff	0	3

Appendix IX: WEMS Index Values for Counties in Arkansas



County	WEMS Factor Scores										WEMS Index Value
	Accessibility to Navigable Inland Waterway	Proximity to Barge Origin	Population Demands	Social Vulnerability	Risk of Disaster					Limited Access to Medical Services	
					Tornado	Earthquake	Flood	Terrorism	Overall		
Baxter	0	3	1	3	1	2	2	2	2	1	0
Boone	0	3	1	2	1	1	1	2	1	1	0
Carroll	0	3	2	1	1	1	2	2	1	2	0
Columbia	0	3	1	2	2	1	2	1	1	2	0
Fulton	0	3	1	3	1	2	1	1	1	1	0
Hempstead	0	3	2	2	1	1	2	1	1	1	0
Howard	0	3	1	1	2	1	2	1	1	3	0
Izard	0	3	1	3	1	2	2	1	1	2	0
Lafayette	0	3	1	2	1	1	2	1	1	3	0
Little River	0	3	2	3	1	1	3	1	1	2	0
Marion	0	3	1	2	1	1	1	2	1	3	0
Miller	0	3	3	2	1	1	2	1	1	3	0
Randolph	0	2	1	3	1	2	2	1	1	2	0
Sevier	0	3	1	2	1	1	1	1	1	2	0
Sharp	0	3	1	3	1	2	2	1	1	3	0
Stone	0	3	1	3	1	2	2	2	2	2	0
Drew	1	2	1	1	1	1	1	2	1	2	7
Ashley	1	2	1	2	2	1	1	1	1	2	8
Clark	1	3	1	1	1	1	3	1	1	2	8
Greene	1	2	2	1	2	3	2	1	2	1	8
Independence	1	3	1	1	2	2	3	1	2	1	8
Bradley	1	3	2	2	1	1	2	2	1	1	9
Calhoun	1	3	1	1	1	1	2	2	1	3	9
Chicot	1	2	1	3	1	1	1	2	1	2	9
Desha	1	2	2	3	1	2	1	2	1	1	9
Johnson	1	3	2	1	2	1	1	3	2	1	9
Lawrence	1	2	2	3	1	2	1	1	1	1	9
Montgomery	1	3	1	1	1	1	1	2	1	3	9
Ouachita	1	3	1	3	1	1	1	1	1	1	9
Phillips	1	2	1	3	1	2	2	2	2	1	9
Pike	1	3	1	2	1	1	2	1	1	2	9
Scott	1	3	2	1	1	1	1	2	1	2	9
White	1	3	2	1	2	2	3	2	2	1	9
Yell	1	3	2	1	1	1	1	3	1	2	9
Sebastian	1	3	3	2	1	1	1	2	1	1	10
Benton	1	3	3	1	2	1	2	1	1	2	10
Clay	1	2	1	3	1	3	2	1	2	2	10
Craighead	1	2	3	2	2	3	3	1	2	1	10
Cross	1	2	2	3	1	3	1	1	1	2	10
Dallas	1	3	2	2	1	1	1	2	1	2	10
Hot Spring	1	3	2	1	2	1	2	2	2	2	10
Jackson	1	2	2	3	3	2	2	1	2	1	10
Monroe	1	2	1	3	1	2	1	2	1	3	10
Nevada	1	3	1	2	1	1	3	1	1	3	10
Polk	1	3	1	3	1	1	1	1	1	2	10

Appendix IX (cont): WEMS Index Values for Counties in Arkansas

County	WEMS Factor Scores										WEMS Index Value
	Accessibility to Navigable Inland Waterway	Proximity to Barge Origin	Population Demands	Social Vulnerability	Risk of Disaster					Limited Access to Medical Services	
					Tornado	Earthquake	Flood	Terrorism	Overall		
Pope	1	3	2	2	1	1	1	3	1	2	10
Union	1	3	2	2	2	1	1	1	1	2	10
Washington	1	3	3	2	1	1	1	1	1	1	10
Saline	1	3	3	1	2	1	2	3	2	2	11
St. Francis	1	2	2	3	1	3	2	1	2	2	11
Arkansas	1	3	2	3	2	2	1	3	2	1	11
Cleburne	1	3	2	2	2	2	2	2	2	2	11
Crawford	1	3	3	2	1	1	1	1	1	2	11
Faulkner	1	3	3	1	3	2	2	2	2	2	11
Garland	1	3	3	3	2	1	1	2	1	1	11
Lee	1	2	2	3	1	2	1	1	1	3	11
Logan	1	3	2	2	2	1	1	3	2	2	11
Mississippi	1	2	2	3	3	3	1	1	2	2	11
Newton	1	3	1	2	1	1	2	3	2	3	11
Perry	1	3	3	1	1	1	2	2	1	3	11
Prairie	1	3	1	2	2	2	2	2	2	3	11
Van Buren	1	3	1	3	2	2	3	3	3	1	11
Woodruff	1	2	1	3	2	2	2	1	2	3	11
Searcy	1	3	1	2	1	2	1	3	2	3	11
Cleveland	1	3	3	2	1	1	1	3	1	3	12
Conway	1	3	2	1	2	2	3	3	3	3	12
Crittenden	1	2	3	3	1	3	2	1	2	2	12
Franklin	1	3	3	2	1	1	3	2	2	2	12
Grant	1	3	3	1	1	1	2	3	2	3	12
Jefferson	1	3	3	3	2	2	1	3	2	1	12
Lincoln	1	3	3	1	1	1	2	3	2	3	12
Poinsett	1	2	3	2	3	3	2	1	2	3	12
Lonoke	1	3	3	2	2	2	2	3	2	3	13
Madison	1	3	3	3	1	1	2	2	1	3	13
Pulaski	1	3	3	3	3	2	2	3	3	1	13

Potential Benefit from Inland Waterway Emergency Medical Services	
⬜	None
🟩	Low
🟨	Medium
🟥	High

Appendix X: Detailed Results of Sensitivity Analysis

County	WEMS INDEX Value	WEMS INDEX Value P-SL	WEMS INDEX Value PD-SL	WEMS INDEX Value SV-SL	WEMS INDEX Value RD-SL	WEMS INDEX Value M-SL	WEMS INDEX Value P-SH	WEMS INDEX Value PD-SH	WEMS INDEX Value SV-SH	WEMS INDEX Value RD-SH	WEMS INDEX Value M-SH
Baxter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carroll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fulton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hempstead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Howard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Izard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lafayette	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miller	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Randolph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sevier	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sharp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drew	7.0	6.8	7.1	7.1	7.1	6.8	7.3	6.8	6.8	6.8	7.3
Ashley	8.0	7.9	8.2	7.9	8.2	7.9	8.2	7.7	8.2	7.7	8.2
Clark	8.0	7.5	8.2	8.2	8.2	7.9	8.6	7.7	7.7	7.7	8.2
Greene	8.0	7.9	7.9	8.2	7.9	8.2	8.2	8.2	7.7	8.2	7.7
Independence	8.0	7.5	8.2	8.2	7.9	8.2	8.6	7.7	7.7	8.2	7.7
Bradley	9.0	8.6	8.9	8.9	9.3	9.3	9.5	9.1	9.1	8.6	8.6
Calhoun	9.0	8.6	9.3	9.3	9.3	8.6	9.5	8.6	8.6	8.6	9.5
Chicot	9.0	8.9	9.3	8.6	9.3	8.9	9.1	8.6	9.5	8.6	9.1
Desha	9.0	8.9	8.9	8.6	9.3	9.3	9.1	9.1	9.5	8.6	8.6
Johnson	9.0	8.6	8.9	9.3	8.9	9.3	9.5	9.1	8.6	9.1	8.6
Lawrence	9.0	8.9	8.9	8.6	9.3	9.3	9.1	9.1	9.5	8.6	8.6
Montgomery	9.0	8.6	9.3	9.3	9.3	8.6	9.5	8.6	8.6	8.6	9.5
Ouachita	9.0	8.6	9.3	8.6	9.3	9.3	9.5	8.6	9.5	8.6	8.6
Phillips	9.0	8.9	9.3	8.6	8.9	9.3	9.1	8.6	9.5	9.1	8.6
Pike	9.0	8.6	9.3	8.9	9.3	8.9	9.5	8.6	9.1	8.6	9.1
Scott	9.0	8.6	8.9	9.3	9.3	8.9	9.5	9.1	8.6	8.6	9.1
White	9.0	8.6	8.9	9.3	8.9	9.3	9.5	9.1	8.6	9.1	8.6
Yell	9.0	8.6	8.9	9.3	9.3	8.9	9.5	9.1	8.6	8.6	9.1
Sebastian	10.0	9.6	9.6	10.0	10.4	10.4	10.5	10.5	10.0	9.5	9.5
Benton	10.0	9.6	9.6	10.4	10.4	10.0	10.5	10.5	9.5	9.5	10.0
Clay	10.0	10.0	10.4	9.6	10.0	10.0	10.0	9.5	10.5	10.0	10.0
Craighead	10.0	10.0	9.6	10.0	10.0	10.4	10.0	10.5	10.0	10.0	9.5
Cross	10.0	10.0	10.0	9.6	10.4	10.0	10.0	10.0	10.5	9.5	10.0
Dallas	10.0	9.6	10.0	10.0	10.4	10.0	10.5	10.0	10.0	9.5	10.0
Hot Spring	10.0	9.6	10.0	10.4	10.0	10.0	10.5	10.0	9.5	10.0	10.0
Jackson	10.0	10.0	10.0	9.6	10.0	10.4	10.0	10.0	10.5	10.0	9.5
Monroe	10.0	10.0	10.4	9.6	10.4	9.6	10.0	9.5	10.5	9.5	10.5
Nevada	10.0	9.6	10.4	10.0	10.4	9.6	10.5	9.5	10.0	9.5	10.5
Polk	10.0	9.6	10.4	9.6	10.4	10.0	10.5	9.5	10.5	9.5	10.0
Pope	10.0	9.6	10.0	10.0	10.4	10.0	10.5	10.0	10.0	9.5	10.0
Union	10.0	9.6	10.0	10.0	10.4	10.0	10.5	10.0	10.0	9.5	10.0
Washington	10.0	9.6	9.6	10.0	10.4	10.4	10.5	10.5	10.0	9.5	9.5

Appendix X (cont.): Detailed Results of Sensitivity Analysis

County	WEMS INDEX Value	WEMS INDEX Value P-SL	WEMS INDEX Value PD-SL	WEMS INDEX Value SV-SL	WEMS INDEX Value RD-SL	WEMS INDEX Value M-SL	WEMS INDEX Value P-SH	WEMS INDEX Value PD-SH	WEMS INDEX Value SV-SH	WEMS INDEX Value RD-SH	WEMS INDEX Value M-SH
Saline	11.0	10.7	10.7	11.4	11.1	11.1	11.4	11.4	10.5	10.9	10.9
St. Francis	11.0	11.1	11.1	10.7	11.1	11.1	10.9	10.9	11.4	10.9	10.9
Arkansas	11.0	10.7	11.1	10.7	11.1	11.4	11.4	10.9	11.4	10.9	10.5
Cleburne	11.0	10.7	11.1	11.1	11.1	11.1	11.4	10.9	10.9	10.9	10.9
Crawford	11.0	10.7	10.7	11.1	11.4	11.1	11.4	11.4	10.9	10.5	10.9
Faulkner	11.0	10.7	10.7	11.4	11.1	11.1	11.4	11.4	10.5	10.9	10.9
Garland	11.0	10.7	10.7	10.7	11.4	11.4	11.4	11.4	11.4	10.5	10.5
Lee	11.0	11.1	11.1	10.7	11.4	10.7	10.9	10.9	11.4	10.5	11.4
Logan	11.0	10.7	11.1	11.1	11.1	11.1	11.4	10.9	10.9	10.9	10.9
Mississippi	11.0	11.1	11.1	10.7	11.1	11.1	10.9	10.9	11.4	10.9	10.9
Newton	11.0	10.7	11.4	11.1	11.1	10.7	11.4	10.5	10.9	10.9	11.4
Perry	11.0	10.7	10.7	11.4	11.4	10.7	11.4	11.4	10.5	10.5	11.4
Prairie	11.0	10.7	11.4	11.1	11.1	10.7	11.4	10.5	10.9	10.9	11.4
Van Buren	11.0	10.7	11.4	10.7	10.7	11.4	11.4	10.5	11.4	11.4	10.5
Woodruff	11.0	11.1	11.4	10.7	11.1	10.7	10.9	10.5	11.4	10.9	11.4
Searcy	11.0	10.7	11.4	11.1	11.1	10.7	11.4	10.5	10.9	10.9	11.4
Cleveland	12.0	11.8	11.8	12.1	12.5	11.8	12.3	12.3	11.8	11.4	12.3
Conway	12.0	11.8	12.1	12.5	11.8	11.8	12.3	11.8	11.4	12.3	12.3
Crittenden	12.0	12.1	11.8	11.8	12.1	12.1	11.8	12.3	12.3	11.8	11.8
Franklin	12.0	11.8	11.8	12.1	12.1	12.1	12.3	12.3	11.8	11.8	11.8
Grant	12.0	11.8	11.8	12.5	12.1	11.8	12.3	12.3	11.4	11.8	12.3
Jefferson	12.0	11.8	11.8	11.8	12.1	12.5	12.3	12.3	12.3	11.8	11.4
Lincoln	12.0	11.8	11.8	12.5	12.1	11.8	12.3	12.3	11.4	11.8	12.3
Poinsett	12.0	12.1	11.8	12.1	12.1	11.8	11.8	12.3	11.8	11.8	12.3
Lonoke	13.0	12.9	12.9	13.2	13.2	12.9	13.2	13.2	12.7	12.7	13.2
Madison	13.0	12.9	12.9	12.9	13.6	12.9	13.2	13.2	13.2	12.3	13.2
Pulaski	13.0	12.9	12.9	12.9	12.9	13.6	13.2	13.2	13.2	13.2	12.3

Appendix X (cont.): Detailed Results of Sensitivity Analysis

County	WEMS INDEX Value	WEMS INDEX Value P-VL	WEMS INDEX Value PD-VL	WEMS INDEX Value SV-VL	WEMS INDEX Value RD-VL	WEMS INDEX Value M-VL	WEMS INDEX Value P-VH	WEMS INDEX Value PD-VH	WEMS INDEX Value SV-VH	WEMS INDEX Value RD-VH	WEMS INDEX Value M-VH
Baxter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carroll	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fulton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hempstead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Howard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Izard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lafayette	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miller	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Randolph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sevier	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sharp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drew	7.0	6.4	7.4	7.4	7.4	6.4	8.5	6.0	6.0	6.0	8.5
Ashley	8.0	7.6	8.6	7.6	8.6	7.6	9.0	6.5	9.0	6.5	9.0
Clark	8.0	6.6	8.6	8.6	8.6	7.6	11.5	6.5	6.5	6.5	9.0
Greene	8.0	7.6	7.6	8.6	7.6	8.6	9.0	9.0	6.5	9.0	6.5
Independence	8.0	6.6	8.6	8.6	7.6	8.6	11.5	6.5	6.5	9.0	6.5
Bradley	9.0	7.8	8.8	8.8	9.8	9.8	12.0	9.5	9.5	7.0	7.0
Calhoun	9.0	7.8	9.8	9.8	9.8	7.8	12.0	7.0	7.0	7.0	12.0
Chicot	9.0	8.8	9.8	7.8	9.8	8.8	9.5	7.0	12.0	7.0	9.5
Desha	9.0	8.8	8.8	7.8	9.8	9.8	9.5	9.5	12.0	7.0	7.0
Johnson	9.0	7.8	8.8	9.8	8.8	9.8	12.0	9.5	7.0	9.5	7.0
Lawrence	9.0	8.8	8.8	7.8	9.8	9.8	9.5	9.5	12.0	7.0	7.0
Montgomery	9.0	7.8	9.8	9.8	9.8	7.8	12.0	7.0	7.0	7.0	12.0
Ouachita	9.0	7.8	9.8	7.8	9.8	9.8	12.0	7.0	12.0	7.0	7.0
Phillips	9.0	8.8	9.8	7.8	8.8	9.8	9.5	7.0	12.0	9.5	7.0
Pike	9.0	7.8	9.8	8.8	9.8	8.8	12.0	7.0	9.5	7.0	9.5
Scott	9.0	7.8	8.8	9.8	9.8	8.8	12.0	9.5	7.0	7.0	9.5
White	9.0	7.8	8.8	9.8	8.8	9.8	12.0	9.5	7.0	9.5	7.0
Yell	9.0	7.8	8.8	9.8	9.8	8.8	12.0	9.5	7.0	7.0	9.5
Sebastian	10.0	9.0	9.0	10.0	11.0	11.0	12.5	12.5	10.0	7.5	7.5
Benton	10.0	9.0	9.0	11.0	11.0	10.0	12.5	12.5	7.5	7.5	10.0
Clay	10.0	10.0	11.0	9.0	10.0	10.0	10.0	7.5	12.5	10.0	10.0
Craighead	10.0	10.0	9.0	10.0	10.0	11.0	10.0	12.5	10.0	10.0	7.5
Cross	10.0	10.0	10.0	9.0	11.0	10.0	10.0	10.0	12.5	7.5	10.0
Dallas	10.0	9.0	10.0	10.0	11.0	10.0	12.5	10.0	10.0	7.5	10.0
Hot Spring	10.0	9.0	10.0	11.0	10.0	10.0	12.5	10.0	7.5	10.0	10.0
Jackson	10.0	10.0	10.0	9.0	10.0	11.0	10.0	10.0	12.5	10.0	7.5
Monroe	10.0	10.0	11.0	9.0	11.0	9.0	10.0	7.5	12.5	7.5	12.5
Nevada	10.0	9.0	11.0	10.0	11.0	9.0	12.5	7.5	10.0	7.5	12.5
Polk	10.0	9.0	11.0	9.0	11.0	10.0	12.5	7.5	12.5	7.5	10.0
Pope	10.0	9.0	10.0	10.0	11.0	10.0	12.5	10.0	10.0	7.5	10.0
Union	10.0	9.0	10.0	10.0	11.0	10.0	12.5	10.0	10.0	7.5	10.0
Washington	10.0	9.0	9.0	10.0	11.0	11.0	12.5	12.5	10.0	7.5	7.5

Appendix X (cont.): Detailed Results of Sensitivity Analysis

County	WEMS INDEX Value	WEMS INDEX Value P-VL	WEMS INDEX Value PD-VL	WEMS INDEX Value SV-VL	WEMS INDEX Value RD-VL	WEMS INDEX Value M-VL	WEMS INDEX Value P-VH	WEMS INDEX Value PD-VH	WEMS INDEX Value SV-VH	WEMS INDEX Value RD-VH	WEMS INDEX Value M-VH
Saline	11.0	10.2	10.2	12.2	11.2	11.2	13.0	13.0	8.0	10.5	10.5
St. Francis	11.0	11.2	11.2	10.2	11.2	11.2	10.5	10.5	13.0	10.5	10.5
Arkansas	11.0	10.2	11.2	10.2	11.2	12.2	13.0	10.5	13.0	10.5	8.0
Cleburne	11.0	10.2	11.2	11.2	11.2	11.2	13.0	10.5	10.5	10.5	10.5
Crawford	11.0	10.2	10.2	11.2	12.2	11.2	13.0	13.0	10.5	8.0	10.5
Faulkner	11.0	10.2	10.2	12.2	11.2	11.2	13.0	13.0	8.0	10.5	10.5
Garland	11.0	10.2	10.2	10.2	12.2	12.2	13.0	13.0	13.0	8.0	8.0
Lee	11.0	11.2	11.2	10.2	12.2	10.2	10.5	10.5	13.0	8.0	13.0
Logan	11.0	10.2	11.2	11.2	11.2	11.2	13.0	10.5	10.5	10.5	10.5
Mississippi	11.0	11.2	11.2	10.2	11.2	11.2	10.5	10.5	13.0	10.5	10.5
Newton	11.0	10.2	12.2	11.2	11.2	10.2	13.0	8.0	10.5	10.5	13.0
Perry	11.0	10.2	10.2	12.2	12.2	10.2	13.0	13.0	8.0	8.0	13.0
Prairie	11.0	10.2	12.2	11.2	11.2	10.2	13.0	8.0	10.5	10.5	13.0
Van Buren	11.0	10.2	12.2	10.2	10.2	12.2	13.0	8.0	13.0	13.0	8.0
Woodruff	11.0	11.2	12.2	10.2	11.2	10.2	10.5	8.0	13.0	10.5	13.0
Searcy	11.0	10.2	12.2	11.2	11.2	10.2	13.0	8.0	10.5	10.5	13.0
Cleveland	12.0	11.4	11.4	12.4	13.4	11.4	13.5	13.5	11.0	8.5	13.5
Conway	12.0	11.4	12.4	13.4	11.4	11.4	13.5	11.0	8.5	13.5	13.5
Crittenden	12.0	12.4	11.4	11.4	12.4	12.4	11.0	13.5	13.5	11.0	11.0
Franklin	12.0	11.4	11.4	12.4	12.4	12.4	13.5	13.5	11.0	11.0	11.0
Grant	12.0	11.4	11.4	13.4	12.4	11.4	13.5	13.5	8.5	11.0	13.5
Jefferson	12.0	11.4	11.4	11.4	12.4	13.4	13.5	13.5	13.5	11.0	8.5
Lincoln	12.0	11.4	11.4	13.4	12.4	11.4	13.5	13.5	8.5	11.0	13.5
Poinsett	12.0	12.4	11.4	12.4	12.4	11.4	11.0	13.5	11.0	11.0	13.5
Lonoke	13.0	12.6	12.6	13.6	13.6	12.6	14.0	14.0	11.5	11.5	14.0
Madison	13.0	12.6	12.6	12.6	14.6	12.6	14.0	14.0	14.0	9.0	14.0
Pulaski	13.0	12.6	12.6	12.6	12.6	14.6	14.0	14.0	14.0	14.0	9.0