SECTION 3

EFFECTS UPON SIX CITIES

3.1 Section Overview

This section begins the presentation and discussion of the findings of this study. The findings are overall estimates which are intended to aid in response planning. General discussions and summaries of findings are presented in subsection 3.2, with individual findings for the six cities being contained in Sections 4 through 9. When appropriate, findings and conclusions have been included in the general section, rather than depicting them in the individual discussion section. The sections on the individual cities include maps showing the estimated ground shaking intensities used for the analyses. Maps depicting ground shaking estimates for the entire CUSEPP region, for both earthquake scenarios, were shown in Section 2, Figures 2-4 through 2-7.

3.2 Medical Resources and Facilities

3.2.1 Major Hospitals

The importance of hospital facilities to a city, and the significance of their damage or loss, cannot be overstated. Hospitals in the six cities, like those in other urban areas, have represented among their numbers all types and varieties of health care facilities. This report studied only major hospitals, i.e. generally those with greater than 100 beds. These six cities also have small, often specialized and usually privately operated, hospitals and clinics; however, they constitute only a small percentage of the total available medical emergency resources.

A major hospital typically encompasses an impressive number of

medical services; normally among these are general medical care, surgery, therapy and rehabilitation, clinical laboratory facilities to provide crucial diagnostic support, X-ray diagnosis equipment, blood banking and emergency and trauma services (with or without hospital-owned ambulances). Many medical centers provide specialized services, for such areas as newborn care, cancer, children's care, and research. Several university affiliated and veterans' hospitals are found in the six cities. All hospitals surveyed had some type of emergency electrical power system. These were usually diesel engine powered, though some were fueled with gasoline and a smaller number with natural gas. Those using natural gas as a fuel will almost certainly lose this fuel source, as well as electric power, following either the Ms=7.6 or the Ms=8.6 earthquake (see discussion of electric and natural gas utilities, later in this section). The systems within individual hospitals which are served by emergency power units vary somewhat among the hospitals surveyed; however, most include the ability to supply power to at least the following items: blood storage and other crucial refrigeration, emergency surgical lighting, X-ray and other crucial diagnostic equipment, selected clinical laboratory facilities, ventilation (but usually not air conditioning). Separate emergency fuel may be provided for heating. The fragility curve analyses of the emergency power units indicate that they can be estimated to be available following the predicted levels of ground shaking in the six cities following the Ms=7.6 earthquake. Many may be unavailable following the Ms=8.6 event.

Estimates of damage to hospitals in the six cities will vary in extent and severity in the same manner as for other damage types.

Table 3-1 gives a summarization of the availability of major hospital facilities, reflected in numbers of estimated available beds and structures following either earthquake scenario. Availability of other hospital services, not addressed elsewhere in this report, can be generally inferred from these availability findings. Specific discussions for each city are found in the individual city sections.

As can be seen from Table 3-1, Memphis will be the most adversely impacted by an occurrence of either earthquake scenario with Poplar Bluff similarly affected. Little Rock is likely to avoid significant losses.

TABLE 3-1

HOSPITAL FACILITIES ESTIMATED TO BE AVAILABLE

City	Ms=7.6 Structures Available (Number/%)	Ms=7.6 Beds Available (Number/%)	Ms=8.6 Structures Available (Number/%)	Ms=8.6 Beds Available (Number/%)
Carbondale	5/83%	190/95%	4/67%	160/79%
Evansville	18/90%	2020/90%	15/75%	1620/72%
Little Rock	24/100%	3760/100%	23/96%	3720/99%
Memphis	13/51%	3230/52%	8/32%	2290/37%
Paducah	6/86%	720/89%	4/57%	600/74%
Poplar Bluff	6/86%	690/90%	5/71%	590/77%
TOTAL	72/92%	10,610/86%	59/76%	8980/73%

3.2.2 Blood Banks

Damage to the contents of blood storage facilities is of obvious concern following any serious disaster. These facilities store whole blood, plasma, other blood components, and additional related items. Blood banks are usually present in major hospitals; these major health facilities include at least short-term (i.e., one-two days usage) storage. Non-hospital blood banks may be commercially owned

or may be operated by an organization, public or private. All facilities found in major hospitals and the majority of those in other locations have emergency electric generators to maintain refrigeration of blood supplies. Loss of this vital cooling is one disaster-related way in which blood stocks may be lost. Another is direct loss caused by damage to the building itself, or damage to the blood by overturning storage shelves and similar events.

Since non-hospital blood banks may be housed in virtually any type of structure, damage to these structures is a factor in the survival of these supplies. The findings presented in the sections for the individual cities depict the likelihood of blood and blood components being available following an occurrence of either postulated earthquake.

3.2.3 Clinical Laboratories

These facilities are mostly found in major hospitals. Larger cities, such as Memphis and Little Rock, have independent clinical laboratories. These facilities are essential for prompt diagnosis of certain illnesses, but play a role of lesser importance following a disaster, with the associated large number of trauma cases. These facilities are very similar to blood banks with respect to their overall availability.

3.2.4 Ambulance Services

Ambulance services are provided in three basic ways: by hospitals, by fire departments or other emergency services, and by private or commercial interests. Each community has a unique approach, but fire departments dominate in providing this service. Ambulance vehicles are very frequently parked outside of structures,

and may be widely dispersed over a city to allow for prompt response. This practice allows for better potential availability of these vehicles than if they were garaged. Their base or "home" structures are vulnerable to damage, and may be of virtually any structural type. These structures contain communication equipment, supplies, and personnel; their availability is an important aspect of the effective and efficient provision of this service.

3.2.5 Casualties among Medical Personnel

The numbers of doctors and nurses in the six cities that would suffer death or serious injury and therefore be unavailable for work are summarized in Tables 3-2 and 3-3, respectively. The tables also express the casualties as percentages of the total number of doctors or nurses in each city.

If either of the earthquake scenarios occurred at night (when most doctors would be at home in relatively safe structures) the number of doctors suffering death or injury is not estimated to exceed 0.3 percent of the total number of physicians in any of the cities except Paducah. The slightly higher casualty estimates in Paducah are a result of the relatively large (and relatively unsafe) non-wood frame residential structures present in the structural inventory data for that city. Casualty estimates are higher in the daytime earthquake scenario with the highest percentage losses occurring in Memphis (2.4 percent for Ms=7.6 and 3.5 percent for Ms=8.6) and Paducah (1.4 percent and 2.2 percent).

Because a greater proportion of nurses would be working at night, the nighttime casualties calculated for nurses are slightly higher than those derived for doctors. The cities suffering the

TABLE 3-2
SUMMARY OF CASUALTY ESTIMATES (DEATHS AND INJURIES) AMONG DOCTORS

City	Number of Doctors	Ms=7.6 Est. Number of Casualties Night	Ms=7.6 Est. Number of Casualties Day	Ms=7.6 % of All Doctors Night	Ms=7.6 % of All Doctors Day	Ms=8.6 Est. Number of Casualties Night	Ms=8.6 Est. Number of Casualties Day	Ms=8.6 % of All Doctors Night	Ms=8.6 % of All Doctors Day
Carbondale	80	0	0	0.1	0.3	0	1	0.2	0.6
Evansville	330	0	2	0.1	0.7	1	5	0.2	1.5
Little Rock	580	0	1	0.0	0.1	0	2	0.0	0.4
Memphis	1,100	2	26	0.2	2.4	4	39	0.3	3.5
Paducah	120	1	2	0.5	1.4	1	3	1.1	2.2
Poplar Bluff	50	0	0	0.0	0.1	0	0	0.1	0.6

TABLE 3-3
SUMMARY OF CASUALTY ESTIMATES (DEATHS AND INJURIES) AMONG NURSES

City	Number of Nurses	Ms=7.6 Est. Number of Casualties Night	Ms=7.6 Est. Number of Casualties Day	Ms=7.6 % of All Doctors Night	Ms=7.6 % of All Doctors Day	Ms=8.6 Est. Number of Casualties Night	Ms=8.6 Est. Number of Casualties Day	Ms=8.6 % of All Doctors Night	Ms=8.6 % of All Doctors Day
Carbondale	390	0	0	0.1	0.1	1	1	0.2	0.2
Evansville	1,400	1	2	0.1	0.2	3	5	0.2	0.4
Little Rock	2,910	0	0	0.0	0.0	0	1	0.0	0.1
Memphis	5,860	26	65	0.4	1.1	43	99	0.7	1.7
Paducah	690	3	2	0.5	0.3	7	6	1.1	0.9
Poplar Bluff	230	0	0	0.0	0.1	0	1	0.2	0.5

largest percentage losses would be Memphis and Paducah, where an Ms=7.6 event (occurring at a point in the New Madrid Seismic Zone closest to each city) would kill or injure 0.4 and 0.5 percent of the total population of nurses, respectively, and Ms=8.6 event (also occurring closest to each city) would result in casualties corresponding to 0.7 and 1.1 percent of the respective total populations. If the Ms=7.6 earthquake scenerio occurred in the daytime, casualties are estimated to exceed 0.3 percent of the total population of nurses only in Memphis, where the estimates would reach 1.1 percent. For a daytime event of the Ms=8.6 scenario, the casualty estimates for nurses do not exceed 0.5 percent of the total population, except in Paducah and Memphis, where 0.9 and 1.7 percent, respectively, are estimated.

It is unlikely that casualties among doctors and nurses in any of the cities would result in significant overall reduction of qualified medical personnel. The casualties would not be evenly distributed among institutions, however, and some hospitals probably would experience a greater loss of staff than others. Damages to highways would also restrict the mobility of medical personnel and make it difficult for them to reach the places where their services are required.

3.3 Public Services

3.3.1 Fire and Police Services:

These services are vital in any emergency. Structures associated with these services typically house personnel, communications centers or base stations, equipment, supplies and vehicles not actually in use. The utility of structures associated

with these services is related to the availability of the structure's contents, wnich may be damaged or destroyed, or be undamaged but inaccessible. A case in point is the jamming of doors of vehicle storage garages. This situation is reportedly common following strong earthquakes and, of course, results in delays in bringing the garaged vehicles into service. The damage to structures associated with these services was assessed and availability estimated. The findings are tabulated in the individual city sections.

3.3.2 Schools

School buildings, due to their size and facilities, can be important locations for shelter and feeding of those persons displaced by the project earthquake, if not too seriously damaged. The number of buildings estimated to be available for such usage is tabulated in the individual city sections, and summarized in Section 3.9.2, "Displaced Persons and Available Shelters".

3.4 Communications

Radio and television stations and transmission structures are significant in their availability to continue or re-establish operations and broadcast vital information to residents of the region. The estimated availability of these structures is tabulated in the individual city sections.

Telephone service was not studied in detail; available information regarding these systems is presented in the individual sections. It was found that the design of many telephone switching centers did include seismic considerations, but this was not universal. The distribution systems are likely to sustain sufficient damage from either earthquake scenario to cause widespread disruption

of service.

3.5 Transportation Systems

Four basic types of transportation infrastructure--highways, railways, river ports and airports--were examined for probable damages in each of the six cities. The impacts which the Ms=7.6 and Ms=8.6 earthquake scenarios would have on the four types of transportation infrastructure are summarized in this section. Details of the analyses are presented in the discussions of the effects on the individual cities.

3.5.1 Highways

As explained in Section 2.4.2, the focus of the highway damage assessment was to determine survival probabilities for each of the sections (links) which constitute the major highway networks in the six cities. A section of a network would survive an earthquake if it were still available for use following the earthquake, having suffered neither severe structural damage or collapse of its supporting structures nor collapse of overpassing structures. Although damage to roadbeds and pavements as a consequence of ground failure was not explicitly incorporated into the analysis, it may be assumed for emergency planning purposes that extensive damage of the latter type would be suffered by roads along river banks and on alluvial deposits in the areas of highest estimated earthquake intensity. However, this type of damage does not preclude use of road areas (e.g. driving over roadsides to avoid damaged pavement) as do failed bridges or overpasses.

Because of the importance of considering potentially impaired access to the cities in preparedness planning efforts, the scope of

the analysis was expanded to include the entire counties in which the six cities are located. The probable effects of the two earthquake scenarios on major highways in the six cities and counties are summarized in Table 3-4.

An earthquake of surface magnitude 7.6 (again, occurring at a point in the New Madrid Seismic Zone closest to the city) would probably cause no damage to highways in and around Little Rock. Neither mobility within the city nor access to the city would be affected according to this study's estimates. In Carbondale, all sections in the city and all but perhaps one in the county probably would survive. Evansville would be likely to lose at most one section in the city and at most one in the county, neither of which would seriously restrict movement into or within the city. In Paducah, perhaps one section would be lost from service inside the city limits. All but perhaps one of the routes entering Paducah from the east, south and west would survive an Ms=7.6 scenario event, but one of the two sections crossing the Ohio River to the north could be closed.

The effects of the Ms=7.6 earthquake scenario would be felt most seriously in Poplar Bluff and Memphis. In Poplar Bluff, at least one of the sections to the east of the bluffs probably would be put out of service. Although access to the city from the west and south may not be affected, the three routes entering the city from the east and the single route entering from the north are all very vulnerable to damage. In Memphis, where half the sections in the city would have a survival probability of less than 0.5, estimated damage is extensive and movement would be seriously restricted. Access to Memphis would

TABLE 3-4

ESTIMATED NUMBER OF HIGHWAY SECTIONS
IN EACH RANGE OF SURVIVAL PROBABILITY

City	Probability of Survival	Number of Sections (City Only)		Number of Sections City + County	
		Ms=7.6	Ms=8.6	Ms=7.6	Ms=8.6
Carbondale	0.00 - 0.25	-	-	-	3
	0.26 - 0.50	-	-	-	1
	0.51 - 0.75	-	1	1	6
	0.76 - 1.00	4	3	15	6
	TOTAL	4	4	16	16
Evansville	0.00 - 0.25	-	1	-	1
	0.26 - 0.50	-	1	-	4
	0.51 - 0.75	1	-	1	2
	0.76 - 1.00	14	13	26	20
	TOTAL	15	15	27	27
Little Rock	0.00 - 0.25	-	-	-	-
	0.26 - 0.50	-	-	-	-
	0.51 - 0.75	1	2	-	2
	0.76 - 1.00	25	24	54	52
	TOTAL	26	26	54	54
Memphis	0.00 - 0.25	23	31	23	36
	0.26 - 0.50	5	7	8	8
	0.51 - 0.75	6	8	10	9
	0.76 - 1.00	20	8	21	9
	TOTAL	54	54	62	62
Paducah	0.00 - 0.25	-	1	-	2
	0.26 - 0.50	-	-	1	6
	0.51 - 0.75	1	4	5	13
	0.76 - 1.00	20	16	44	29
	TOTAL	21	21	50	50
Poplar Bluff	0.00 - 0.25	-	2	6	11
	0.26 - 0.50	1	2	4	4
	0.51 - 0.75	3	-	3	-
	0.76 - 1.00	6	6	13	11
	TOTAL	10	10	26	26

TABLE 3-4

ESTIMATED NUMBER OF HIGHWAY SECTIONS
IN EACH RANGE OF SURVIVAL PROBABILITY (Page 2)

City	Probability of Survival	Number of Sections (City Only) Ms=7.6	Number of Sections (City Only) Ms=8.6	Number of Sections City + County Ms=7.6	Number of Sections City + County Ms=8.6
All Six Cities					
	0.00 - 0.25	23	35	29	53
	0.26 - 0.50	6	10	13	23
	0.51 - 0.75	11	14	20	32
	0.76 - 1.00	89	70	173	127
	TOTAL	129	129	235	235

probably be interrupted on at least half the major routes entering the city.

The scenario earthquake of surface magnitude 8.6 would cause slight damage in and around Little Rock, perhaps making impassable one or two sections in the city (where the most vulnerable section would be one of the Arkansas River crossings) and one or two outside the city. Mobility would not be significantly impaired. All major highway sections in Carbondale would probably survive, as would the access routes from the south and east, but access from the north and west could be lost. Two or three sections would probably be removed from service in Evansville, the greatest risk being in the southwestern corner of the city. Access from the west and south would be restricted, although it is unlikely that all routes would be cut.

An Ms=8.6 scenario event would block perhaps three to five of the 21 major highway sections in Paducah. Outside the city, both

sections crossing the Ohio River to the north could be cut. Access from the east and west would probably be significantly reduced but not totally lost, whereas access from the south would probably not be affected. In Poplar Bluff, two or three of the four sections to the east of the bluffs would probably be removed from service, and all access from the east and north would probably be lost. Access from the west would probably still be available.

In Memphis, the Ms=8.6 scenario event, according to this study's estimates, would leave very few major highway sections available for use, severely restricting mobility throughout the city. At least one of the two Mississippi River crossings would probably be damaged. All but two or three of the eleven access routes into the city would probably be closed.

3.5.2 Railroads

The same approach employed in the analysis of highway damage was also followed in the estimate of damages to the major railway networks. The analysis did not, however, consider potential damages to signalling systems, nor did it explicitly address the problems which would be caused by misaligned tracks and damaged switches or potential damages to tracks and roadbeds as a consequence of ground failure, since the data required were not available. The probable effects of the two earthquake scenarios on major rail lines in the six cities and counties as a consequence of structural damages are summarized in Table 3-5.

The scenario earthquake of surface magnitude 7.6 would cause no significant damage to railway structures in and around Little Rock and would be unlikely to close any sections in or around Evansville.

TABLE 3-5

ESTIMATED NUMBER OF RAILWAY SECTIONS
IN EACH RANGE OF SURVIVAL PROBABILITY

City	Probability of Survival	Number of Sections (City Only)		Number of Sections City + County	
		Ms=7.6	Ms=8.6	Ms=7.6	Ms=8.6
Carbondale	0.00 - 0.25	-	-	-	4
	0.26 - 0.50	-	-	-	5
	0.51 - 0.75	-	1	1	2
	0.76 - 1.00	3	2	12	2
	TOTAL	3	3	13	13
Evansville	0.00 - 0.25	-	-	-	-
	0.26 - 0.50	-	-	-	1
	0.51 - 0.75	-	4	-	4
	0.76 - 1.00	17	13	24	19
	TOTAL	17	17	24	24
Little Rock	0.00 - 0.25	-	-	-	-
	0.26 - 0.50	-	-	-	-
	0.51 - 0.75	-	2	-	2
	0.76 - 1.00	13	11	33	31
	TOTAL	13	13	33	33
Memphis	0.00 - 0.25	12	18	12	20
	0.26 - 0.50	2	5	3	7
	0.51 - 0.75	6	1	8	1
	0.76 - 1.00	7	3	8	3
	TOTAL	27	27	31	31
Paducah	0.00 - 0.25	-	1	-	2
	0.26 - 0.50	-	1	-	5
	0.51 - 0.75	1	2	3	2
	0.76 - 1.00	11	8	18	12
	TOTAL	12	12	21	21
Poplar Bluff	0.00 - 0.25	-	1	1	4
	0.26 - 0.50		2	1	2
	0.51 - 0.75	1	-	2	-
	0.76 - 1.00	3	1	5	3
	TOTAL	4	4	9	9

TABLE 3-5

ESTIMATED NUMBER OF RAILWAY SECTIONS
IN EACH RANGE OF SURVIVAL PROBABILITY (Page 2)

City	Probability of Survival	Number of Sections (City Only) Ms=7.6	Number of Sections (City Only) Ms=8.6	Number of Sections City + County Ms=7.6	Number of Sections City + County Ms=8.6
All Six Cities					
	0.00 - 0.25	12	20	13	30
	0.26 - 0.50	2	8	4	20
	0.51 - 0.75	8	10	14	11
	0.76 - 1.00	54	38	100	70
	TOTAL	76	76	131	131

In Carbondale, although no section would be closed within the city limits, two or three of the ten sections outside the city would probably be impassable. Access to the city from the south would probably not be affected. One of the 12 sections in Paducah would probably be cut. With the possible exception of the ICG (Illinois Central Gulf Railroad Line) crossing the Ohio River, all lines providing access to Paducah would probably survive the Ms=7.6 scenario event.

The Ms=7.6 earthquake scenario would be likely to interrupt at least one of the four sections in Poplar Bluff and would probably eliminate rail access to the city from the north and east, leaving access possible only from the south. In Memphis, close to half the sections of the major rail lines would be impassable. North-south movement would be seriously restricted, and only one of the two railway bridges across the Mississippi River would be likely to survive. Outside the city, a similar situation would prevail, with

only two or three lines estimated to continue to provide access.

The surface magnitude 8.6 earthquake scenario would cause little or no damage to the railway network in Little Rock. At most one section inside the city and one section outside the city would incur any structural damage that would affect its use. At greatest risk would be the two Union Pacific (UPAC) structures across the Arkansas River. Evansville could lose two of the 17 sections inside the city limits as well as access to the city from the south. Carbondale would probably retain its access from the south, but access from the east and west could be lost.

In Paducah, the Illinois Central Gulf and Pacific and Illinois (ICG-P&I) line crossing the Ohio River to the north would probably be interrupted both inside and outside the city limits. One or two other sections in the city could be left impassable, and one or two of the four lines entering the city from the east, south and west would probably also be closed.

The 8.6 surface magnitude earthquake scenario would probably damage rail structures in Poplar Bluff so severely that none of the three lines entering the city would remain passable, and two of the four sections inside the city would be removed from service. In Memphis, only a few rail sections would be operable, and movement within the city would generally be infeasible. Both rail bridges across the Mississippi River to the west would probably be closed. Access to the city would be severely restricted; at most one line would be likely to remain open, either from the south or east.

3.5.3 River Ports

The inland waterway system that meanders throughout most of the

study area has precipitated much waterfront land development, both port facilities and waterside located production facilities. The port facilities are either private terminals or public terminals. The waterside production facilities are all private and typically have their own private port terminals.

Private port terminals are, of course, designed and operated to meet the unique, particular needs of the shipper or receiver who built them.

Public port terminals, on the other hand, are available to all shippers or receivers. They generally provide docks, wharfs, loading and unloading equipment, warehouses, tank farms and open storage for all types of commodities that move by barge. Most public terminals have railroad and highway connections which permit the direct interchange of freight between barges and land based transportation.

The commodities particularly attracted to inland water-borne transportation are raw materials, moving in large quantities from one stage of production and processing to the next. Many heavy, bulky semifinished (as well as finished) products are also moved by barge. The principal commodities handled on the inland waterway system, as determined by a 1979 Commerce Department study are coal, petroleum and petroleum products, grains, construction materials, and chemicals. These items account for about 75 percent of the total inland traffic by tonnage. Two of the commodity groups, coal and petroleum products, constitute approximately 50 percent of the waterborne traffic in the Mid-America region, with coal alone contributing almost one third of the total tonnage.

Waterfront development is typically located in the relatively

flat land adjacent to the inland waterway system. These sites are frequently in the flood plain of the river which consists of alluvial deposits of the river. The geologic nature of these sites combined with the heavy loading common in waterfront development creates severe foundation problems. Low bearing strength, differential settlement, and slope instability are often design concerns in these areas. High and frequently fluctuating groundwater levels are also a problem.

During either of the earthquake scenarios of this study, significant destruction is estimated in the waterfront development areas. The movement of the earth in combination with the types of soils found in the areas and the typically high groundwater will create severe liquefaction problems. The resulting loss of bearing strength would sever pipelines and conveyors, rupture storage tanks, topple warehouse buildings and dock facilities, crack and displace paved storage areas, and render most other facilities unusable.

3.5.4 Airport Facilities

Within or near the six cities of this study there are a variety of airports, both privately and publicly owned. Normally, private facilities are small, single runway (often turf-surfaced) facilities. They may or may not have lighting and they do not typically have navigation aids. Publicly owned airports range in size and complexity from small private facilities serving general aviation traffic, to large multi-directional runway facilities capable of serving commercial air carriers. Airport facilities of the small, non-complex type typically have one hard-surface runway, simple navigation lighting, simple directional navigation aids and visual