F O R

E M E R G E N C Y R E S P O N S E P L A N N I N G

P U R P O S E S

O N L Y

The primary purpose of this report is to assist emergency managers and planners in the development of response plans to deal with the consequences of major earthquakes in the central United States. This report is not intended for any other use.

In particular, the probabilistic methods which underlie the estimation of damage to structures and the resulting casualties, were developed and applied to yield such estimates only for groupings or aggregations of structures of similar types or purpose. For the level of analysis performed for this report, these techniques were not intended to provide damage descriptions for individual structures. No attempt should be made to use the findings of this report for other than the above stated purpose.

AN ASSESSMENT OF DAMAGE AND CASUALTIES FOR SIX CITIES IN THE CENTRAL UNITED STATES RESULTING FROM EARTHQUAKES IN THE NEW MADRID SEISMIC ZONE

FEDERAL EMERGENCY MANAGEMENT AGENCY

Central United States Earthquake Preparedness Project

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EXECUTIVE SUMMARY

I - General

The Central United States Earthquake Preparedness Project (CUSEPP) is an on-going effort to reduce the hazards associated with earthquakes through determination of the potential consequences of major earthquake events in the New Madrid Seismic Zone, an increase of the awareness of those consequences among public officials and the private sector, the development of response plans for coping with them, and the implementation of actions for reducing them. This report, supported by estimates of ground shaking developed by the U.S. Geological Survey, provides preliminary estimates of the potential consequences of two major sizes of earthquakes in six cities within or near the seismic zone. These cities are: Little Rock, Arkansas; Carbondale, Illinois; Evansville, Indiana; Paducah, Kentucky; Poplar Bluff, Missouri; and Memphis, Tennessee. The cities were chosen on the basis of several factors: 1) population size in relation to the preliminarily identified areas of damage intensities, 2) architectural types and, 3) cooperative environment of the city to be studied. Only those parts of the urbanized area actually within the designated corporate limits of each city were surveyed and studied.

The earthquake effects studied are based upon the ground shaking estimates of two sizes of events, having surface magnitudes (Ms) of 7.6 and 8.6. The reader will note that the effects on the six cities combined are maximized since the estimate of ground shaking assumes that the epicenter of each earthquake scenario is located as close to each city as possible within the entire New Madrid Seismic Zone. The

Ms=8.6 event allows assessment of the upper limits of damage and needs. The 7.6 earthquake represents an event with a greater probability of occurrence, and can be viewed as more appropriate for realistic risk assessment and subsequent emergency management measures.

The selection of these magnitude events for CUSEPP planning is reasonable from at least two points of view. First, such earthquakes have actually occurred in this region; each of the "great" earthquakes of 1811 and 1812, which are widely referenced in earthquake literature, had surface magnitudes above 8.0 on the Richter Scale and approximate the size of the larger (Ms=8.6) earthquake. The 1811-1812 series also included hundreds of aftershocks, many with magnitudes estimated to be between 6.5 and 7.6. Second, recent earthquake research has theorized that current strain in the New Madrid Seismic Zone would create a Ms=7.6 earthquake if it were all released today and, further, that the probability for the occurrence of such an event during the life span of existing and planned structures and the lifetime of persons now living does exist.

The occurrence of either Ms=8.6 or Ms=7.6 earthquakes would result in damages, disruption, casualties, and injuries on a scale never experienced from a natural hazard in the history of this nation; the immediate and long term relief and recovery efforts would place a significant, prolonged burden upon the regional and national economy.

Of equal, if not greater importance is the fact that earthquakes of lesser, yet significant, power are much more likely to occur.

Moderate sized earthquakes are a very real hazard for the CUSEPP planning area. The serious (though localized) damage in Coalinga, California which resulted from the May 2, 1983 event (6.5 on the Richter Scale), demonstrates the damage which can be caused to an area by a moderate earthquake that does not have a high level of seismic design in construction. Due to the different soil conditions and overall lack of adequate seismic design in structures in the Mississippi Valley region, a New Madrid quake could be expected to cause much more extensive and widespread damage than resulted from an event of similar magnitude in California. However, since expected effects of the moderate sized event are encompassed within the effects of the events examined here, a separate scenario for the moderate event is not presented.

To estimate the effects of earthquakes (magnitudes 7.6 and 8.6) in the New Madrid Seismic Zone on the six cities, the following procedures were employed. Structural inventory and critical facilities data were collected and supplemented in some cases by further investigations. Estimated levels of ground shaking in the six cities are expressed in Modified Mercalli Intensities and were provided by the U.S. Geological Survey for both the Ms=7.6 and Ms=8.6 earthquakes. These estimates depict ground shaking intensities which would be expected if each earthquake's epicenter were as close as possible, along the fault zone, to each studied city. On the Modified Mercalli Intensity scale, these estimates ranged between V and X. To assess expected structural damage, a series of fragility curves, (which describe the probability of damage states as a function of the level of ground shaking), were developed for sixteen different types

of structures common to the six cities. These structural types included buildings, utility plants and systems, dams, bridges and storage tanks. The fragility curves were applied to the inventoried structures, usually grouped according to a function, to determine the expected damages at the ground shaking intensities estimated for the structure's location. Casualty estimates were based on the expected number of occupants of the buildings and the level of damage estimated to occur to them. Average building occupancies were derived from census data, employment data and inventory data. Restoration and replacement costs were estimated for those structures and systems for which damage estimates were made and were based on average construction costs in the cities studied, and the damage sustained. These determinations of damage, casualties and costs are preliminary estimates derived from implementation of a preliminary vulnerability assessment methodology and should be utilized accordingly.

If exposed to an occurrence of either of the postulated earthquakes, the six project cities would suffer varying effects. The following sections of this summary are a discussion of the overall effects and probable consequences for the six cities.

II - Casualties

The number of casualties (deaths and injuries) resulting from occurrence of either of the postulated events would depend on the time of day at which it occurred. At night, most of the population is found in relatively safe wood frame residential structures, but during a typical working day the majority of the population moves to buildings which are much more vulnerable to severe structural damage

or collapse. A substantial proportion of the daytime casualties would occur among school children. Total daytime deaths in the six cities could easily exceed 4,500, as shown in the following summary:

Total Estimated Deaths
Due to Structural Failure

	Ms=7.6 Event			Ms=8.6 Event		
	Night	Day	School Deaths as % of Day Deaths	Night	Day	School Deaths as % of Day Deaths
Memphis	211	2523	26	435	3786	27
Paducah	47	116	18	101	201	19
Carbondale	29	74	30	69	160	25
Evansville	23	227	32	58	492	32
Poplar Bluff	1	17	88	4	52	81
Little Rock	3	64	16	9	216	17
Total	314	3021	26(avg.)	676	4907	27(avg.)

III - Medical Services

Medical services in the six cities would be severely burdened to provide adequate care for all injured persons requiring medical attention, except perhaps in Little Rock. Outside assistance may be a viable consideration for planners to alleviate this situation. Health care professionals would encounter difficulty reaching their places of work, and a few (less than two percent) would be among the dead and injured. The normal availability of beds and medical supplies would be reduced because of severely damaged or collapsed hospital structures. Memphis would be the most severely affected as seen in the following table.

City	Hospital Structures Surveyed	Hospital Beds Estimated to be Available			
		Ms=7.6 Event		Ms=8.6 Event	
		Number	% of Total	Number	% of Total
Memphis	25	3230	52	2290	37
Paducah	7	720	89	600	74
Evansville	20	2020	90	1620	72
Poplar Bluff	7	690	90	590	77
Carbondale	6	190	95	160	79
Little Rock	13	3760	100	3720	99
Total	78	10,610	86 (Avg)	8980	73 (Avg)

Most of the cities would not have sufficient surviving beds to accommodate the number of major injuries estimated in this report in addition to their normal load of patients. Other services would be similarly affected. The number of seriously injured persons requiring prompt medical attention would be about four times the number of deaths in each city. Additional casualties could also result from fires and flooding.

IV - Transportation Systems

Damage to transportation systems would seriously hamper rescue and relief efforts and would have an extensive adverse effect upon regional and national commerce.

Highway access to Memphis as well as major highway availability within the city would be severely limited for both seismic events. With the Ms=7.6 event, the most probable surviving access route would be U.S. 72 from the east; bridge collapses would either cut or block most, but probably not all, of the eight other principal arteries into the city. Poplar Bluff would be vulnerable to loss of highway access from the east. Paducah's highways would suffer some damage, but no serious loss of accessibility would result. Little loss of highway accessibility would occur in Carbondale and Evansville, and

almost no serious highway damage would take place in Little Rock.

Damage to railway networks would follow a pattern similar to the highway damages. Little Rock would probably suffer no loss in rail accessibility; Evansville would experience little or none. Carbondale could suffer impaired accessibility from the west, while Paducah is most vulnerable to rail losses to the north (crossing the Ohio River) and from the east. The cities likely to suffer greatest disruption are Poplar Bluff and Memphis. Rail access from all directions into Poplar Bluff would be at risk of serious impairment, though not to the extent expected in Memphis, where over 75% of all system sections have relatively low survival probabilities.

These assessments are based on the likelihood of collapse of highway and railway structures. Some of the rail and highway structures which did not collapse would suffer severe damage that would restrict or prevent their use by heavy vehicles.

For both earthquakes, railway traffic would be stopped for as long as required to inspect all structures in each line segment, possibily 24 to 48 hours. For that reason, the most immediate transportation needs into and out of the six cities would have to be met via highway and air transport, and possibly by river access, although port facilities are likely to be seriously damaged.

River ports are expected to be extensively disrupted, with the minimum disruption occurring in Little Rock. The cities of Carbondale and Poplar Bluff do not possess river port facilities and thus would not be directly affected. Memphis, Evansville and Paducah are expected to sustain substantial damage to their river ports facilities.

Partial or limited availability of major airport facilities is expected following either earthquake. Those facilities at airports which rely on electrical power, e.g., navigation aids and runway lighting, may be out of commission for a period of time, even if emergency power is available. Runways may be available, at least for limited use, even in cities closest to the fault zone. Runways may sustain certain kinds of damage but still have enough useable length to allow landings and takeoffs of aircraft bearing vital supplies. The loss of navigation and landing aids can be significant, especially during winter when weather conditions are frequently marginal or below landing minimums.

V - Utility Systems

The six cities studied, for both earthquake events, are expected to experience serious impairment or loss of their four main utility systems (electric, water, gas, and sewers). Little Rock will lose availability of all systems in an Ms=8.6 event but may not lose availability of all systems for the Ms=7.6 event. Those which are out-of-service after the Ms=7.6 event are likely to be restored relatively quickly. Systems in the other five cities, for both events, will be unavailable for periods of days to months due to likely shortages of supplies, equipment and workers to restore the systems. The most essential and, unfortunately, the most vulnerable of the utility networks, are the electric power systems. So many things depend upon the availability of electric power that even its short term loss, under normal conditions, is a major setback to a community. To superimpose a loss of electric power upon a severe and widespread disaster can mean, for example, no water to fight fires or

for drinking and sanitation; no light or heat; no communications; and no sewage pumps. The following summary presents the estimated availability of utility systems for the six project cities for the Ms=7.6 event. All systems are expected to be unavailable for the Ms=8.6 event.

Estimated Availability of Utility Systems
Ms=7.6 Event

City	Electric	Water	Gas	Sewer
Memphis	U	U	U	M *
Little Rock	U *	A	M *	A
Evansville	U	U	U	U
Paducah	U	U	U	U
Carbondale	U	U	U	U
Poplar Bluff	U	U	U	U

U - System likely to be unavailable.
M - System may be available.
A - System likely to be available.
* - Limited and/or modified use possible.

VI - Critical Facilities

In addition to the examination of critical lifeline systems (utilities, hospitals, communications and transportation), the six cities' vulnerability to earthquakes includes an assessment of facilities that will be crucial to each community's ability to conduct and monitor its immediate response to the estimated losses, particularly those involving life protection. These facilities include police and fire stations, ambulance services, blood banks and clinical laboratories. In general, Little Rock and Evansville were found to be the relatively least vulnerable to damages to these structures while Memphis, Poplar Bluff and Paducah are the most vulnerable.

VII - Flooding

Were the earthquake to occur at a time when high water conditions (i.e. 100 year flood) existed in the area's rivers and streams, flooding of low-lying areas, now protected by levees, is likely to occur. This is because levees are expected to be damaged sufficiently to allow flooding behind them. Earthen dams, however, are not expected to be damaged to the extent that they will lose their reservoirs. This finding, combined with the situation that low or flood-prone areas in the six cities are mostly undeveloped and unoccupied, indicates that relatively few casualties would be expected due to flooding following the postulated seismic events. Flooding would, however, result in displaced persons and would hamper relief efforts.

VII - Fires

Giant fires, or conflagrations, involving major portions of the six cities are unlikely as a direct result of the scenario earthquakes, due to the nature and density of construction. Widespread individual or small-group structural fires are likely, however, due to miscellaneous damage-related factors, (i.e. gas leaks, flammable liquid spills, electric shorts, etc.), and loss of fire suppression capabilities.

VIII - Shelter Requirements

Many individuals will require shelter when their dwellings are rendered uninhabitable by actual earthquake-caused damage, flooding and other causes. These persons may have available alternative shelter in surviving, relatively undamaged structures (following

inspections). The following is a listing of the estimated numbers of persons requiring shelter in the six cities:

Persons Likely to Require Shelter
Due to Damage to Residence

City	Due to Flooding	Ms=7.6 Event	Ms=8.6 Event
Memphis	10,100	231,680	353,800
Little Rock	3,500	2,440	21,700
Evansville	24,600	11,095	38,900
Paducah	5,000	13,318	22,600
Carbondale	-	5,728	11,100
Poplar Bluff	-	5,743	10,600
Total	43,200	270,004	458,700

Section IX - Restoration/Replacement Costs

The financial and economic burden placed upon the region and the entire nation by an occurrence of such a disaster would be very great. The following summarizes a part of such costs (restoration and replacement) for the six cities.

Estimated Restoration/Replacement Costs
(Millions of Dollars)

City	Ms=7.6 Event Structures	Utilities	Total	Ms=8.6 Event Structures	Utilities	Total
Memphis	$22,095	2,908	25,003	27,609	4,071	31,680
Little Rock	1,463	454	1,917	2,886	955	3,841
Evansville	4,781	360	5,141	7,395	595	7,990
Paducah	3,002	1,395	4,397	3,846	1,952	5,798
Carbondale	809	257	1,066	1,185	387	1,572
Poplar Bluff	558	135	693	858	217	1,075
Total (Millions of Dollars)			$38,217			$51,956

X - Summary

In summary, the impact of either the Ms=7.6 or Ms=8.6 earthquake on the six cities would be massive and could cause widespread disruption, damage, and casualties. Remaining resources within the affected region would be unable to adequately provide for the emergency response needs of these communities. This indicates that very large scale outside support and assistance of all kinds may be the primary means to reduce further loss of life, suffering and disruption to regional lifelines. It is hoped that the information contained within this report will be a meaningful step toward the development of appropriate national, regional and local response plans, and longer range strategies.

XI - Organization of this Report

The material contained in this report can be divided into two major areas. The first, Sections 1 and 2, describes the overall project and its methodology. The second, Section 3, is a presentation of the project's findings and consists of an initial general section which contains discussions of each results category, and which also presents findings and conclusions pertaining to all or most project cities collectively. Then follow the six sub-sections presenting and discussing the findings for each project city. An estimation of replacement and restoration costs, glossary, abbreviations list and a bibliography conclude the report.

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