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EMERGENCY PREPAREDNESS AND RESPONSE:  
LESSONS FROM THE LOMA PRIETA EARTHQUAKE

Kathleen J. Tierney

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## **EMERGENCY PREPAREDNESS AND RESPONSE: LESSONS FROM THE LOMA PRIETA EARTHQUAKE**

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### **INTRODUCTION**

One of the most costly and damaging disasters in U. S. history, the 1989 Loma Prieta earthquake was the largest earthquake to strike California since 1952 and the most devastating to hit the San Francisco Bay Area since 1906. From the earliest hours following impact, as initial reconnaissance efforts got under way, it was evident that Loma Prieta would become an important case study for the various disciplines concerned with earthquake hazard reduction. Because Loma Prieta presented such an obvious opportunity to learn more about the earthquake hazard, an unprecedented number of studies were undertaken in the earth sciences, engineering, and the social sciences. At this point, a little more than three years after the event, an enormous amount of data have been collected and a lot has been learned on a wide range of topics. This paper focuses on the lessons for emergency preparedness and response that have resulted from that research. After presenting a brief overview of research on Loma Prieta, the paper considers research findings and practical implications related to the actions of individuals, households, and the public at large; groups and organizations; and government agencies and the intergovernmental system.

### **OVERVIEW OF PREPAREDNESS AND RESPONSE STUDIES**

Loma Prieta was the most damaging earthquake to strike a major metropolitan area in the U. S. since the passage of the National Earthquake Hazard Reduction Act (NEHRP) in 1977. One of the original objectives of NEHRP was to foster needed research on earthquakes, and since the program was established the size of the research community in the earthquake field had grown considerably. Thus, when Loma Prieta struck, a large number of investigators were able to go into the field almost immediately to begin collecting data, and ultimately dozens of studies were undertaken on a wide range of topics. The Natural Hazards Research and Applications Information Center at the University of Colorado, which provides "quick response" grants mainly to social science investigators, was an important source of funding for initial reconnaissance studies on emergency preparedness and response following Loma Prieta. The Hazards Center monograph The Loma Prieta Earthquake: Studies of Short-Term Impacts (1990) is a compilation of reports from nineteen investigators who conducted studies on the emergency response and initial impacts of Loma Prieta. As it does for all significant earthquakes (but this time on a very large scale) the Earthquake Engineering Research Institute undertook a major reconnaissance effort following Loma Prieta, which was coordinated in the social sciences and emergency response areas by Robert Olson and Charles Scawthorn. Reports of the various EERI reconnaissance teams are

summarized in a special issue of Earthquake Spectra (Earthquake Engineering Research Institute, 1990).

Following the earthquake, both the National Science Foundation and the U. S. Geological Survey augmented their existing grant programs to sponsor additional studies, some of which focused on emergency preparedness and response. Findings from much of that research are still in the process of being released as part of the U. S. Geological Survey Professional Paper Series. One collection of social scientific reports in this series, edited by Patricia Bolton, was recently published (Bolton, 1993). The National Center for Earthquake Engineering Research also provided support for reconnaissance studies, longer-term research, and other activities, including partial funding for a conference on post-earthquake housing issues that focused on Loma Prieta as well as other recent U. S. earthquakes (National Center for Earthquake Engineering Research, 1992).

Because of the large number of researchers involved, the comparatively large amount of funding that was provided, and the size and sophistication of many of the studies that were undertaken, there are probably more data available on the Loma Prieta earthquake than on any other disaster. Efforts such as the National Clearinghouse for Loma Prieta Earthquake Information, organized by the National Information Service for Earthquake Engineering (NISEE) help ensure that these data are preserved and used.

It would not be possible for this paper or any other short paper to discuss in detail all the reports on emergency preparedness and response that resulted Loma Prieta. Rather, the paper will highlight some of the more important findings and lessons learned, referring readers who desire more detail to those longer reports.

## HOW THE PUBLIC RESPONDED IN LOMA PRIETA: INDIVIDUAL AND HOUSEHOLD RESPONSES

Several studies on Loma Prieta provide useful data on how the public responded when the earthquake struck and during the post-impact emergency period. Among the most important of these are studies on the initial post-impact actions of community residents, earthquake-related injuries, emergency sheltering behavior, and the public response to aftershock warnings.

### Actions During the Shaking Period

Using a survey approach like the one they employed after the 1987 Whittier Narrows earthquake, Linda Bourque, James Goltz, and their associates conducted a telephone survey with a random sample of 656 respondents in the five counties most seriously affected by Loma Prieta. The survey focused on a number of topics, including what people did during and immediately after earthquake impact; property damage and injuries; decision-making with respect to evacuation; psychological distress at the time of the interview; earthquake preparedness actions taken before and after the earthquake; reliance on the mass media after impact; exposure to aftershock warnings; and contacts with public agencies following Loma Prieta.

With respect to immediate actions upon impact, the survey found that the most common responses during the shaking, taken by nearly three-fourths of respondents, were to freeze in place; to seek protection; or to freeze and then seek protection. The researchers observed that workplace disaster preparedness programs must be having an effect because a significant proportion of those who were at work or in schools at the time of the earthquake reported taking self-protective actions during the shaking. Research conducted by Rahimi and Azevedo (1993) with a sample of disabled persons following Loma Prieta suggests that like the individuals in the Bourque/Goltz sample, people with disabilities were also able to initiate appropriate actions to protect themselves during earthquake shaking--although they may be less able than the non-disabled to gain access to personal items and emergency supplies after earthquake impact.

Running during earthquake shaking is not considered appropriate because it may result in injury. A small number of respondents in the Bourque/Goltz survey indicated they ran at the time of impact; running was more likely to be reported nearer the earthquake epicenter and more likely to be reported by young males, indicating that this group may be less aware such behavior is dangerous. About 40% of the people who were at home when the earthquake struck reported going to help a child during the shaking period--an action that may have increased personal risk.

This study on individual post-impact responses revealed other interesting patterns. For example, persons who were not at home, work, or in some other familiar setting but who instead found themselves in public places when the earthquake struck seemed less able than other respondents to take decisive self-protective action. Public places are less familiar than the home or workplace, and people may be confused about what to do to protect themselves in those settings. On the basis of this finding, the researchers suggested that:

Procedures need to be developed that allow people to identify and act on "generic" information about locations which can then be generalized from one location to another. In particular, people need to know how to scan and quickly assess a location for safety, and how to behave in the presence of large numbers of other people so that they do not endanger themselves and others (Bourque, Russell, and Goltz 1993b:2-14).

For more detailed discussions of these survey findings, see Bourque, Aneshensel, and Goltz (1991); Bourque, Russell, and Goltz, 1993a; and Bourque, Russell, and Goltz (1993b).

John Archea (1990) interviewed 41 Santa Cruz residents who were in their homes at the time of the earthquake, obtaining detailed reconstructions of what people did during the shaking period. His preliminary data indicate that during the 10- to 12-second period of strong shaking, building occupants engaged in a variety of actions, including seeking refuge from moving and falling objects; simply staying as still as possible and "riding out" the shaking (likely equivalent to the "freezing in place" described in the Bourque/Goltz survey); attempting to protect property by bracing or propping it up; and trying to go outside. A few respondents were unable to initiate any action at all during the shaking. Archea observes that while the majority of those interviewed actively tried to protect themselves, "they also unwittingly took some risks to do so, and many were still at risk 10 or 12 seconds later when the shaking stopped" (1990: 63).

Evidence from Loma Prieta suggests that Bay Area residents were aware of what to do when an earthquake strikes and that even during the strong shaking period they were capable of making choices and taking actions to decrease their vulnerability. Public education programs are paying off. At the same time, the programs aren't reaching everyone who needs them, and some people continue to take unnecessary risks.

### Injuries

Reports on the distribution of various types of injuries differ somewhat, due to differences in the data sources and classification systems used. Tierney (1991) reports that

approximately 1,100 persons were seen in hospitals in the six-county area of impact for earthquake-related injuries and medical complaints on the night of the earthquake; of this number, 73% were treated and released. Most of the injuries were not severe. Wounds, abrasions and contusions, fractures, and sprains and strains, the most commonly treated injuries, accounting for more than half of the total. Durkin, et al. (1991), using data from the California Department of Industrial Relations and the Office of Emergency Services, found a similar pattern: strains, sprains, and contusions constituted 60% of the shaking-related injuries and 70% of the post-shaking injuries.

The survey conducted by Linda Bourque, James Goltz, and their colleagues after the earthquake sought data on the entire population in the affected area, rather than only persons who visited hospital emergency departments or made injury claims. In that study, a very small number of people in the randomly-selected sample--7 out of the 656 persons surveyed--reported having been injured in the earthquake. The likelihood of being injured was highest for residents of the hardest-hit areas of Santa Cruz County; about 3.3% of those surveyed reported having been injured (Bourque, Russell, and Goltz, 1993b). These rates of reported injury differ from those found by some investigators, as discussed in more detail below. However, they are consistent with injury rates these same investigators found following the Whittier Narrows earthquake.<sup>1</sup> In the Whittier Narrows event, the injury rate was 26 per 1,000 residents in the area of severest earthquake shaking; in Loma Prieta, the rate was 32.8 per 1,000 in the hardest-hit area of Santa Cruz County (Bourque, Russell, and Goltz, 1993).

After the earthquake a multidisciplinary team of researchers began collecting data on Santa Cruz county residents who died and who were treated at hospitals for earthquake-related injuries, as well as on a randomly-selected control group matched by area of residence. The objective of the study was to identify risk factors for death and injury, as well as for injury severity. Based on earlier studies, the researchers hypothesized that such risk factors would include various attributes of the physical environment in which the individual is located at the time of the earthquake, such as building type; the behaviors undertaken by the individual, such as self-protective actions; whether the individual was able to move at the time of impact; sociodemographic characteristics of the individual, such as age; aspects of the setting at the time of impact, such as whether the individual was alone or with others; and other risk factors, such as whether the

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<sup>1</sup> That is, the injury rates differ moderately, but in the expected direction. Loma Prieta was a larger earthquake, covering more area, with a longer period of strong shaking. Soil conditions amplified the ground shaking in some areas, which doubtless contributed to the incidence of injuries during the shaking period.

individual had preexisting medical problems or disabilities. Data collection on this study is complete; data having been obtained on 483 persons in the injured/killed sample and 701 persons in the control group. (For detailed discussions of analyses that have been conducted to date, see Jones, et al, 1992; Wagner, et al., 1993; Jones, et al., 1993).

Detailed findings are not yet available on specific risk factors, but this study has already provided some very useful information. For example, the data on when deaths and injuries occurred indicate that while the majority happened at the time of earthquake shaking, a rather high proportion--about 40%--occurred within the 72-hour time period after the earthquake, suggesting it may have been possible to prevent some of these later injuries, for example by issuing advisory warnings to the public. In conducting the population survey to obtain the "non-injured" control group, the investigators also found that 15% of those contacted reported actually having been injured in the earthquake, even though they did not seek hospital treatment for their injuries. A similar pattern is discussed in reports by Durkin et al. (1991) and Thiel et al. (1992) which indicate that as many as 60% of those with earthquake-related injuries either treated themselves or received treatment in non-hospital settings. These findings suggest that a substantial number of earthquake-related complaints were dealt with outside the formal health care system. They also raise the question why some injured persons elected to seek hospital treatment while others did not.

However, as noted earlier, the findings from studies on overall numbers and rates of injuries resulting from Loma Prieta are not consistent. It is unclear why one survey (Bourque, et al.) found that roughly 3% of respondents in the most severely affected communities in Santa Cruz County were injured, while another (Jones, et al.) suggested that the countywide percentage may have exceeded 15%. Such discrepancies could be due to a number of factors: the wording of questions about injuries; how soon after the earthquake the surveys were conducted; the time period covered by the questions (e.g., during and immediately after the earthquake vs. a longer period of time); the context within which the survey questions were asked; or the approaches used in establishing sampling frames and selecting samples.

With respect to the risk factors examined to date, data from the Santa Cruz injury study conducted by Jones and his collaborators indicate that being inside a building rather than outside when earthquake shaking began meant that a person had a 3.3 times greater risk of being injured. Studies using other data sets also reveal some intriguing patterns related to injury risk. Durkin, et al. (1991) and Durkin and Thiel (1992), focusing on 18 earthquake fatalities and 325 injuries defined as "work-related," found that all but one of the fatalities were due to some form of

structural failure<sup>2</sup>. Of the injuries occurring during earthquake shaking that were not related to structural collapse, 26% were attributable to falls (particularly stairway falls), and another 21% occurred when people were thrown against objects. Falling and overturning objects accounted for another 28% of the injuries. These researchers also found that taking protective action (getting under a desk, standing in a doorway) was sometimes associated with injury, but those injuries tended to be minor. They suggest that while the recommended self-protective actions may enhance life-safety in collapse-hazard situations, people who rush to protect themselves in other less hazardous settings may be increasing their risk of minor injury<sup>3</sup>.

### Evacuation and Use of Emergency Shelter

The earthquake caused many residents of the Bay Region to vacate their homes, either temporarily or permanently, and to seek various forms of emergency shelter. Bourque, et al. (1992) found that overall 22% of the respondents in their survey reported having evacuated for at least some period of time. Propensity to evacuate varied according to the severity of earthquake effects, with the highest proportion of residents (about 43%) evacuating in the heavily damaged areas of Santa Cruz County. Most of the respondents in this sample returned to their homes within 24 hours.

The study found that the tendency to evacuate was higher nearer the earthquake's epicenter and higher for respondents whose homes suffered damage. However, an important lesson this earthquake brought out is that physical earthquake effects such as damage and loss of utilities were by no means the sole factor explaining evacuation. Many people with such damage did not evacuate. A substantial proportion of those did evacuate (up to half of the respondents in the five-county survey) reported doing so for reasons that were unrelated to physical damage levels, such as emotional upset, fear of aftershocks and further damage, and concern about the safety of their children.

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<sup>2</sup> Forty-two of the 62 deaths attributed to the earthquake occurred in the collapse of a single structure--the Cypress freeway. The other major cause of death was the total or partial collapse of unreinforced masonry buildings.

<sup>3</sup> Findings like these should be considered preliminary and suggestive, however. Research on how people get killed and injured in earthquakes is still in a very rudimentary stage, and much of the work done to date has been methodologically flawed. When the data from Loma Prieta are analyzed fully, more information will be available on who got injured and how than exist for any other earthquake. Nevertheless, many more studies will be needed before it will be possible for researchers to develop adequate explanations for earthquake-related mortality and morbidity.



As is the case in most disasters, the majority of evacuees made their own sheltering arrangements after the earthquake, mainly staying with friends and relatives or camping outside near their homes. Regarding "official" shelter use, Bolin and Stanford (1990) report that at the peak period 2,500 displaced persons were being provided with shelter nightly, about 20% of the estimated 12,000 to 13,000 left homeless. By the end of the third week after the earthquake, all but about 500 of those displaced were either relocated into temporary housing or back in their homes.

Studies of the provision of temporary shelter after Loma Prieta have revealed some interesting patterns with important policy implications. First, the research clearly shows that post-earthquake temporary shelter needs are closely related to a community's pre-earthquake housing problems. For example, in Loma Prieta, those most likely to be displaced were low-income persons, usually tenants, who had inhabited older, low-rent properties before the earthquake--properties that were already in poor condition and very short supply. Those people also needed to remain in shelters longer than is usually the case in U. S. disasters, because with so many units destroyed and uninhabitable, it was more even more difficult after the earthquake for them to find suitable housing<sup>4</sup>. Homelessness was already a problem in the Bay Area before the earthquake. Loma Prieta damaged homeless shelters and a number of the single-room-occupancy hotels that are an important source of housing for the very poor, and as a result homeless people and those at risk of becoming homeless were even worse off after the earthquake than before.

Second, although disaster assistance agencies may intend shelters to be used by disaster victims only, definitions of who constitutes a "victim" may differ. For example, in some communities affected by Loma Prieta, because there was already a significant homeless population and a shortage of housing, "pre-disaster homeless" persons attempted to utilize shelter facilities and other services. Some of these individuals did not meet the official eligibility requirements for disaster assistance. Although it was the position of the agencies that disaster aid was not meant to address what they considered pre-existing community problems, community groups argued that programs should try to meet the needs of everyone affected by a disaster, rather than defining eligibility in strict bureaucratic terms.<sup>5</sup>

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<sup>4</sup> One of the Santa Cruz County shelters remained open for sixty-six days after the earthquake--an extremely long period for a "temporary" shelter (Phillips, 1991).

<sup>5</sup> Following Loma Prieta, the Federal Emergency Management Agency (FEMA) was severely criticized for disaster assistance policies that were believed to discriminate against low-income households, members of the homeless population, and people in

Third, Loma Prieta showed clearly that as the major metropolitan areas of the U. S. become increasingly ethnically and racially diverse as a consequence of immigration and other population trends, the population requiring post-disaster sheltering and other services will reflect that diversity. It will be necessary to tailor assistance programs to the needs of program users rather than delivering "generic" services in a standardized manner. (For more detailed discussions of housing issues, see Bolin and Stanford, 1990; Phillips, 1991; Phillips and Hutchins, 1991; and Bolin, 1993.)

### Response to Aftershock Warnings

Following the M7.1 mainshock, numerous aftershocks occurred, and aftershock warnings continued to be issued to the public over a two-month period. Dennis Mileti and Paul O'Brien studied how residents of San Francisco and Santa Cruz Counties responded to these aftershock warnings. They found that most people were aware of the aftershock warnings, particularly in Santa Cruz County, and many respondents (66% in San Francisco County and 75% in Santa Cruz County) believed damaging aftershocks would occur. By two months after the earthquake, substantial numbers of people had taken one or more additional preparedness measures, such as protecting household items from damage, and again this tendency was more pronounced in Santa Cruz County. However, the people most likely to pay attention to and act on aftershock warnings were those who had experienced damage in the mainshock and who subsequently got involved in the community emergency response. People who weren't affected by the mainshock tended to do less in response to aftershock warnings, leading the researchers to conclude that (Mileti and O'Brien, 1992: 53)

Those who experience little or no loss in the impact of a disaster may be prone to a "normalization bias" when interpreting post-impact warnings for subsequent risk: "the first impact did not effect me negatively, therefore, subsequent impacts will also avoid me."

Such a conclusion would, of course, be unwarranted, and future aftershock warning efforts should emphasize that point. (For further discussions, see O'Brien and Mileti, 1992; Mileti and O'Brien, 1992; 1993).

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transient living situations (General Accounting Office, 1991). A class action lawsuit filed against FEMA in 1989 resulted in a out-of-court settlement earmarking FEMA funds specifically for the reconstruction of housing for low-income Bay Area tenants.

## RESPONSE OF GROUPS, ORGANIZATIONS, AND INTERORGANIZATIONAL NETWORKS

A disaster of the magnitude of Loma Prieta causes the mobilization of a vast range of organizational and community resources; it is probably fair to say that at the peak of the emergency thousands of different organizations and tens of thousands of people were involved in the response. Obviously, it was not possible for researchers to collect data systematically on all the individuals and organizations that performed disaster-related tasks. However, certain aspects of the response were well-studied, and a considerable amount was learned about how some types of organizations handled disaster-generated demands and coordinated their activities. This section focuses on some of the more important groups, organizations, and networks that were involved in the emergency response, including emergent groups and volunteers, local first-response agencies, hospitals and emergency health-care providers, transportation networks, utility lifeline organizations, and governmental emergency response agencies.

### Emergent Groups and Volunteers

Researchers have long been aware that disasters are invariably accompanied by an increase in altruistic or pro-social behavior on the part of the public (Barton, 1970; Dynes, 1970; Drabek, 1986). Loma Prieta was certainly no exception to this pattern. A survey conducted by O'Brien and Mileti (1993) with a representative sample of residents in Santa Cruz and San Francisco counties found that a large majority of residents in both counties--70% in Santa Cruz and 60% in San Francisco County--participated in some type of emergency response activity following the earthquake. Among the most widely reported activities were providing food and water to others (35% in Santa Cruz, 14% in San Francisco); helping with clean-up and debris removal (44% in Santa Cruz, 11% in San Francisco); providing shelter to others (18% in Santa Cruz, 12% in San Francisco); and providing counseling to victims (17% in Santa Cruz, 8% in San Francisco). Three percent of San Francisco respondents and about 5% of Santa Cruz respondents reported engaging in emergency search and rescue activities. Although these percentages seem small, when extrapolated to the entire population of those counties, they add up to more than 31,000 search and rescue volunteers. Clearly, the response by the public was massive following Loma Prieta, and a large share of the assistance that was provided to victims was given through informal channels.

Groups comprised wholly or partly of volunteers were a critical element in the emergency response effort. Such groups ranged from organizations with formal, longstanding disaster responsibilities like the Red Cross to newly-formed building damage inspection crews and emergent search and rescue groups. Focusing specifically on the initial response to the Cypress Structure collapse, Garcia, Honeycutt, and Van Anne (1993), note that

community residents were massively involved from the earliest moments after impact, rescuing trapped motorists, helping victims to safety, and giving first aid. These volunteers provided assistance that was desperately needed, often putting themselves at risk to do so. However, because the volunteer response was so large, coordination of volunteers became a major challenge.

No comprehensive research has been conducted on the formation, activities, and effectiveness of volunteer groups in the emergency response period. However, Neal (1990) was able to examine the activities of nine volunteer organizations in one community following Loma Prieta. These organizations included the Red Cross, the Salvation Army, an amateur radio group, and a local volunteer coordinating council. Among Neal's conclusions were that volunteer organizations were relatively effective even though their activities were often not well-coordinated with those of local government. Effective task performance for this group of volunteer organizations was related to (1) degree of prior disaster planning; (2) degree of prior disaster experience; and (3) the degree to which the organization had established ties with other important community organizations before the earthquake.

#### Local Emergency Response Activities

The mobilization of emergency resources following Loma Prieta was massive, and the resources available were in most cases far exceeded the actual demand. As the discussions below will indicate in more detail, except in those communities near the epicenter such as Santa Cruz and Watsonville, the emergency response system was not stressed in Loma Prieta, even during the period of peak demand on the night of the earthquake. However, the disruption and demands produced by the earthquake were sufficient to suggest where problems might develop in future earthquakes. Key emergency response tasks are discussed briefly below.

#### Search and Rescue

No major analytic reports on search and rescue activities following Loma Prieta have been released; the accounts published to date are mainly descriptive. However, based on existing reports, it appears that except for the large-scale organized effort that developed at the Cypress Structure and smaller formal rescue actions undertaken in the Marina District in San Francisco and the Pacific Garden Mall in Santa Cruz, the majority of the search and rescue that took place following the earthquake was conducted informally by community residents. And even in these more formally-organized efforts, residents of the damaged areas and other volunteers played a major role.

Descriptions of the extensive search and rescue operation that was undertaken at the Cypress Structure can be found in the City of Oakland's After Action Report (1990), EERI's Reconnaissance Report

(1990), and a report on the activities of the Oakland Fire Department by Garcia, Honeycutt, and Van Anne (1993). Those documents make the following observations about that search and rescue effort:

There were major difficulties with interorganizational communication because so many different responding agencies with different radio frequencies were involved.

Convergence of personnel, vehicles, and equipment, made management and coordination of search and rescue difficult at times.

Convergence by the mass media also created problems.

An overall Incident Command System was difficult to institute because so many different agencies responded, and many responders were either unfamiliar with the system or used different versions.

Rescue operations were hindered initially because of the lack of heavy rescue equipment and portable lighting.

Community residents, ranging from persons living in the immediate vicinity to contractors and other individuals with specialized equipment, volunteered in the search and rescue effort in large numbers. Their contributions were extremely valuable, but because of the sheer number of people wanting to provide assistance, coordination problems did occur.

### Emergency Medical Services

Hospitals, ambulance companies, EMS agencies, and other emergency medical care providers were the subject of considerable study following Loma Prieta. Despite the fact that several components of the EMS system were damaged and disrupted by the earthquake, overall response capacity was not compromised. Major damage was confined to a small number of hospital facilities near the epicenter; Watsonville Community Hospital was particularly hard-hit but remained functional (for detailed information on damage, see EERI, 1990). Nonstructural damage to hospitals was widespread in the area of impact, but the damage by and large was not severe enough to interfere with patient care. Of the various components of the emergency medical care system, communications facilities such as the "911" dispatching centers were perhaps the most seriously affected by the earthquake. Difficulties with EMS communications and dispatching stemmed from a variety of sources: earthquake-induced power failures; damage to the buildings in which the facilities were housed; damage to critical equipment, such as computers; loss of computer-aided dispatching capability; disruptions in communications (particularly phone communications) between the centers and the outside community; damage to message

transmission facilities; and excess radio traffic that made communications difficult (EERI, 1990; Tierney, 1991).

In their study on the operations of the "911" communications center in Santa Cruz County, Durkin et al. (1991) found that while the volume of calls was much higher than normal on the night of the earthquake and record-keeping suffered as a result, EMS personnel were able to respond to all requests for assistance. When dispatched into the field that night, emergency workers adjusted to the increased demand in several ways:

several patients were treated and released by the EMS crews; multiple individuals were transported in one run to a hospital; patients were directed to other means of transport if available; and no action was taken when the crew determined that their services were not critical. There was an unusually high number of cases where the ambulance arrived and found that other medical resources were already on the scene (Durkin, et al., 1991: 2158-2159).

The victims transported by EMS personnel during the emergency period were less seriously injured than those normally seen, requests for emergency assistance were extremely high only on the night of the earthquake, and the demand for EMS services dropped back to normal levels within about three days.

Ambulance personnel were available in very large numbers throughout the Bay Area on the night of the earthquake; in fact, there was an oversupply of emergency vehicles, paramedics, and EMTs in most of the damaged areas. Off-duty staff reported to area hospitals immediately following impact, and hospital personnel who were surveyed after the earthquake indicated that personnel and resources were more than adequate to deal with the medical problems that were seen (Tierney, 1991; Pointer, et al., 1992).

The emergency medical care system functioned well in the earthquake, largely because (1) system capability was quite high in the area affected by the earthquake, as indicated by the quantity and quality of EMS resources; (2) essential health-care resources survived the earthquake well, while flexible and redundant system components compensated for damaged and disrupted elements; and (3) the earthquake produced a comparatively small number of casualties relative to system capability, and most of the medical complaints that resulted were not severe (Tierney, 1991). However, the earthquake also showed there is a need to improve the ability of EMS systems to handle greatly increased numbers of calls, to determine rapidly which of those callers have the greatest need for specialized emergency services, and to allocate resources to the areas of greatest need (Thiel, et al., 1992). Many of those who went to hospitals and requested emergency assistance from other EMS providers did not have injuries and medical problems severe enough

to require those specialized resources. More attention needs to be paid to how large numbers of minor injuries will be handled in future earthquake events, particularly catastrophic earthquakes. Such efforts will obviously have to involve educating the public not to use emergency resources for non-emergencies.

### Damage Assessment

Early Identification of Problem Areas. Early efforts to identify the areas that had been hardest-hit in the earthquake were complicated by the fact that communications were sporadic and the information available to response agencies was incomplete. Initial media reports greatly overestimated the number killed and injured, and by focusing on dramatic instances of damage the media (particularly television) gave the impression that the earthquake produced widespread destruction. The reports highlighted the damage in media-accessible areas like the Marina District, underrepresented the losses in smaller, more remote areas like Santa Cruz and Watsonville, and failed to put the amount of damage that had been done into perspective (Rogers, et al., 1990).

Since media reporting is known to be selective, it is not advisable to rely on mass media reports of disaster impacts. However, in the absence of solid data, the initial impressions that were formed about the extent and location of the damage following Loma Prieta--both by the general public and by emergency responders--were heavily influenced by media accounts. For example, local officials in Santa Cruz County, seeing the Marina District fires and the Bay Bridge damage on television, assumed the devastation was so widespread it was pointless to ask for resources from other counties (City of Watsonville, 1990).

Evaluation of Damaged Buildings. Systematic damage assessment to identify potentially unsafe structures began very soon after impact. Loma Prieta was the first earthquake in which the Applied Technology Council's Procedure for Post-Earthquake Safety Evaluation of Buildings (ATC-20) was used on a broad scale for this purpose.<sup>6</sup> Oaks (1990), focusing on how the evaluation process worked in San Francisco following Loma Prieta, makes several observations. First, aftershocks complicated the damage assessment process, often making multiple inspections necessary; most red- and yellow-tagged buildings were reinspected an average of four times during the first week. Second, the damage caused by the earthquake also exposed asbestos in many of the buildings, which engendered controversy. Third, because the cost of Phase 3 evaluations must be borne by the property owner and decisions about what to do with buildings take time to make, the evaluation process for some

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<sup>6</sup> The evaluation guidelines had been published only a short time before the earthquake, and very few people had received training in their use.

damaged structures tended to get drawn out over time. Fourth, the damage assessment process sparked landlord-tenant disputes, e.g., when tenants were unwilling or unable to reoccupy buildings, or when landlords used the earthquake as an occasion to evict tenants. Fifth, ATC-20 focuses on evaluating buildings, but contains no directives for organizing and managing that evaluation effort--a monumental undertaking in a major earthquake.<sup>7</sup>

The damage assessment process and uncertainty about the safety of structures contributed to the ongoing need for shelter:

Because of the ever-changing conditions, great resources were required in terms of time and personnel to carry out the reinspections and reassessments. The changing conditions also contributed to many social, economic, and legal problems that occurred as people were unable to continue to live in their homes or pursue their means of livelihood. For example, until buildings were inspected and considered safe for occupancy, it was uncertain if people could reinhabit certain structures. As a result, neighborhood and city resources faced demands for emergency sheltering (EERI, 1990: 413).

Oaks (1990) notes that despite these difficulties damage assessment activities in San Francisco went quite smoothly. This was due in large measure to the fact that there were so many trained, qualified persons ready to work as inspectors and because of the involvement of organizations like the Office of Emergency Services Volunteer Engineer Program and the California Association of Building Officials. Other evaluations of the ATC-20 process (e.g., Seismic Safety Commission, 1991) were also positive. Loma Prieta clearly showed that the management of damage assessment activities is a critical task in the emergency response period. However, it also raises the question of whether other communities would be able to handle the task as well as those in the Bay Area.

#### Response of Public Transportation Networks

The collapse of the Cypress Structure and the closing of the Bay Bridge and two other major San Francisco highways due to earthquake damage seriously disrupted transportation patterns in the Bay Area. San Francisco, Oakland, and the Bay Area in general faced the possibility of spiraling economic losses unless alternative modes of transportation could be developed to compensate for the loss of these key routes. Bay Area

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<sup>7</sup> This comment was not meant to imply that ATC-20 should have done so--that was not the intention of the guidelines--but rather to suggest that organizing damage assessment is a significant task in and of itself, separate from the technical decision-making that goes into the evaluation of buildings.



transportation agencies had not been involved in earthquake preparedness planning to any great degree prior to Loma Prieta. After the earthquake, these agencies became involved in intensive efforts to devise new transportation modes and routes that would bypass damaged connections in the system. Several hundred individuals and more than a dozen transportation agencies (including Bay Area Rapid Transit, Alameda/Contra Costa Transit, San Mateo County Transit, San Francisco Municipal Bus, the Golden Gate Bridge and Transit Services, and private ferry companies) participated in this effort. The system of transportation that was developed following the earthquake was especially critical during the first month after the earthquake, when the Bay Bridge remained closed. The existence of coordinating agencies like the Metropolitan Transportation Commission, the Transit Operators Coordinating Council, and the Regional Transit Association, as well as the fact that the various transportation agencies had a history of working together before the earthquake helped, the improvised system to get organized rapidly.

### Lifeline Organizations

Loma Prieta was in many respects a "lifeline disaster." Among the most dramatic examples of lifeline impacts were the collapse of the Cypress Structure, the closures of the Bay Bridge, major highways in San Francisco, and Highway 17 due to damage, the loss of water for firefighting in the Marina District, and the damage to the Moss Landing electric power substation. The major lifeline organizations in the Bay Area are highly prepared for disasters, particularly earthquakes. Many lifeline organizations had also been engaged in earthquake hazard mitigation activities prior to the earthquake that reduced damage and disruption. The high level of emergency preparedness was the principle reason why it was possible to restore lifeline services so rapidly after the earthquake. Large lifeline service providers like Pacific Gas and Electric documented their emergency response activities extensively and produced after-action reports discussing lessons learned in the earthquake (c.f., Phillips and Virostek, 1990). These reports are an important resource for both utilities and local governments seeking to improve their response capability.

Lifelines are focused on in depth in the paper prepared for this conference by Ronald Eguchi, so they will not be discussed in detail here. One lesson that does warrant emphasis, however, is that many emergency response activities depend upon lifeline systems in order to be effective, and lifeline damage can thus seriously impact community response capability. Isenberg (1991), for example, has documented the ways damage to lifelines affected emergency response capacity in Watsonville after Loma Prieta. Because of the loss of electrical power, for example, the city's emergency communications center could not function; it was difficult to pump gasoline from underground tanks; in order to get power, extensive use had to be made of emergency generators, which

created additional problems; and hospital operations were adversely affected.

A related lesson from Loma Prieta involves the extent to which the various lifeline services are interdependent. Electrical power is perhaps the most crucial service, because so many other lifelines need power in order to operate. Because lifeline services are so important to the overall community response, it is critical that linkages be maintained between lifeline organizations and local community officials for both pre-disaster preparedness and post-disaster response. Similarly, lifeline interdependence requires that the organizations providing different lifeline services engage in joint preparedness planning and coordinate their emergency activities.<sup>8</sup>

#### Local and State Emergency Response Agencies

The earthquake did damage over an 8,000 square kilometer area with a population of about 4 million people; six counties and dozens of local jurisdictions were affected. Except for large-scale multijurisdictional efforts like the Cypress Structure search and the activation of some mutual aid agreements, jurisdictions generally handled their own emergency response problems without much outside assistance. No systematic research was conducted on the effectiveness of local emergency management systems following Loma Prieta. However, many jurisdictions and organizations developed their own assessments of how well emergency tasks were performed and outlined the lessons they had learned (c.f., County of Santa Cruz, 1990; City of Watsonville, 1990; City of Oakland, 1990). Hearings conducted by the California Seismic Safety Commission in affected jurisdictions also focused on emergency response issues and problems (see Seismic Safety Commission, 1991).

The report of the State/Federal Hazard Mitigation Survey Team (1990) identified the following response-related needs that were highlighted by Loma Prieta:

Formal procedures for the Federal response to a major but not catastrophic earthquake;

More specific planning to assign responsibility for all Emergency Support Functions (ESFs) in the Federal Response Plan;

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<sup>8</sup> Such coordination was easier in the Bay area following Loma Prieta than it would be in many other communities because Pacific Gas and Electric provides natural gas and power to the entire Northern California region. More commonly, the various lifeline services are provided by separate organizational entities, which hampers integration in planning and response activities (Tierney, 1992).

Policies and criteria to enable Federal and State agencies to provide automatic assistance to local jurisdictions for time-critical response elements;

A model emergency management structure and procedures, common to local, State, and Federal response agencies;

Enhanced communications systems at the Federal, State, and local levels;

A systematic approach to collecting data on damage;

A model resource tracking system for State and local jurisdictions;

The identification of staging areas for various resources;

The establishment of regional planning groups (e.g., in the Bay Region) to address response-related issues of regional concern;

Emergency medical service mutual aid agreements for OES regions, and a mutual aid plan for the provision of emergency fuel;

Efforts to address regional emergency transportation planning;

Increases in a broad range of emergency resources: generators, fuel supplies, search and rescue equipment, medical supplies;

Lists of Federal, State, and local personnel who are capable of performing post-earthquake building inspections;

Increased capacity to provide short-term shelter to earthquake victims;

Increased capacity to provide timely public information in earthquake situations.

The Seismic Safety Commission's report Loma Prieta's Call to Action (1991), which was developed with input from officials in several hard-hit communities, makes a number of observations and recommendations in the area of emergency response that warrant mention here:

Local capabilities were sufficient to meet emergency response needs, but this does not mean the Bay Area is ready for a larger earthquake.

Earthquake preparedness planning, disaster drills, and related activities helped local jurisdictions respond more effectively.

The lack of accurate information on which areas were most severely affected hampered the emergency response in the early

hours and made some jurisdictions hesitant to request outside resources.

A significant number of law enforcement, medical, and fire resources were provided through mutual aid agreements, and these arrangements generally worked well.

The State Office of Emergency Services should be authorized to send resources to areas impacted by an earthquake automatically, regardless of whether local jurisdictions make specific requests.

Guidance is needed on how to manage post-earthquake damage assessment activities.

The State's emergency management system should be expanded and improved, and "a standardized Emergency Management System" (California Seismic Safety Commission, 1991: 23) should be developed for all governmental emergency organizations.

Training of emergency managers and responders needs greater emphasis.

Although areas needing improvement are noted, the tone of the report is positive. It emphasizes the continuing need to overcome well-known barriers to better emergency management: budget shortages; the uneven quality of local emergency management resources (e.g., EOCs, communications equipment) and personnel; the use of inconsistent planning frameworks across local jurisdictions; limited State authority to mandate preparedness activities; and cumbersome rules about requesting and providing resources in disasters.

In light of what occurred last year in Florida following Hurricane Andrew, it is interesting to note that both the Seismic Safety Commission report and the Hazard Mitigation Team report stress the need for mechanisms to ensure the automatic provision of aid, bypassing the requirement that local jurisdictions (or states) must formally request resources from higher governmental levels in emergency situations.

In July of 1991, the Bay Area Regional Earthquake Preparedness Project convened a symposium to bring together officials from the cities of San Francisco, Oakland, and Los Angeles to discuss lessons the Bay Area cities learned from Loma Prieta and determine whether Los Angeles's planning assumptions needed to be modified on the basis of the Loma Prieta experience. The conference focused on five main areas of concern: managing the disaster response; issues related to public works; emergency shelter and housing; financial issues; and community and business preparedness. The report on the joint symposium (Governor's Office of Emergency Services, 1992) contains dozens of findings and specific recommendations on such topics as the management human resources in the disaster response

period; coordination with the mass media; damage assessment and control of access to damaged sites; interagency coordination; debris removal; demolition; code changes; emergency shelter and housing recovery policy; and financing mitigation and preparedness. Clearly these three cities learned many lessons from the Loma Prieta experience and are currently using that experience to enhance emergency management policy and planning.

### Intergovernmental Coordination

Preparations for a major earthquake had been extensive throughout California for many years, but the event itself did contain a number of unexpected elements. The Federal government, already overextended as a consequence of Hurricane Hugo only three weeks before, understandably had some difficulty organizing another major assistance effort in California. State and local governments faced a very challenging situation: a major earthquake affecting a large, densely populated, multijurisdictional region. Obviously, the event required considerable intergovernmental coordination. Like local emergency response activities generally, intergovernmental coordination was not the subject of intensive study following the earthquake, but it was addressed in some reports. In one study that focused on the emergency response to both Hurricane Hugo and Loma Prieta, Schneider characterizes intergovernmental coordination in the earthquake as reasonably effective but somewhat disorganized (1990: 111):

Despite greater general preparedness, some officials still had difficulty coping with the disaster...local officials often were not familiar with their responsibilities or with the role of other government agencies. Some expected the federal government to do everything. More commonly, local officials tried to do things that FEMA (or some other federal agency) was supposed to do. Their actions seemed appropriate and necessary at the time, but they disrupted the functioning of the intergovernmental system.

Following Hurricane Hugo and Loma Prieta, the U. S. General Accounting Office undertook a study of the performance of Federal government agencies in disaster response and relief activities. Much of the report focuses on Federal activities and responsibilities related to recovery, but emergency response issues are also touched upon. The GAO report assesses the response favorably, noting that "California's level of preparedness contributed to its ability to respond to the earthquake with relatively few problems" (1991:20) and that "A FEMA exercise that tested the catastrophic earthquake plan--two months before the earthquake--contributed greatly to a well-coordinated response" (1991: 22). But the report goes on to identify ways in which the response effort might have been improved, pointing out that standard operating procedures for state emergency operations

centers were inadequate or lacking; that many Federal agencies did not have sufficient staff available to perform critical functions adequately; that FEMA's emphasis on war preparedness left many staff ill-prepared to provide services in disasters; and that in providing emergency assistance, the Red Cross by its own admission was "culturally insensitive to victims, and did not have appropriate bilingual skills to serve some communities" (1991: 41). The report argues that deficiencies in the emergency response may be due to the fact that there is no government agency (at the Federal or any other level) that can monitor preparedness activities and require local jurisdictions to perform their response-related roles effectively.

#### CONCLUDING COMMENTS

Research on the public and organizational response to Loma Prieta reemphasized many old lessons. Among these lessons are that disasters create an outpouring of altruism, but this massive response can in itself create coordination problems; that people behave adaptively in disaster situations, and public education can improve their chances of remaining safe; that when organizations show a real commitment to disaster preparedness, those preparedness efforts increase organizational effectiveness when disaster strikes; and that disasters invariably produce unexpected challenges for responders, calling for flexibility and the willingness to develop innovative solutions.

At the same time, Loma Prieta also pointed to emerging problems and needs in the emergency response area. It pointed out, for example, that as communities in the U. S. change and become more culturally diverse, organized efforts to provide assistance to disaster victims must also change to accommodate that diversity. It showed that when disasters exacerbate pre-existing community problems such as housing shortages and homelessness, agencies need to have policies in place to address those problems and to be willing to innovate. Loma Prieta also revealed the need for better coordination among the various levels of government, particularly mechanisms to enable agencies to dispense with red tape and facilitate the deployment of resources to areas where they can do the most good. Additionally, it highlighted the fact that while some communities and states are extremely well prepared to respond in major emergencies, many others are not. With so many lives and so much property at risk, it is imperative to further explore policy mechanisms that would maintain the capacity of those states and localities May (1991) terms the "leaders" in hazard reduction, while enhancing the capacity of the "laggers."

Finally, perhaps the most important lesson of the Loma Prieta earthquake is that the investment made in mitigation and preparedness pays off. Loma Prieta showed that the Bay Area has made impressive progress in improving its ability to reduce damage

and to cope with the problems created by earthquakes. But it would be a mistake to extrapolate from the Loma Prieta experience to larger events that the Bay region's faults could produce. Rather than creating complacency, the earthquake should serve as a warning for what the Bay Area, California, and other earthquake-prone areas of the country can expect future events. It should also serve as a sobering reminder to communities in California and around the country that still have not made a commitment to reducing earthquake hazards. They can expect many more severe problems in earthquakes comparable to Loma Prieta, and they may be truly devastated by larger ones.

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