Paper No. 439. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3
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USE OF RAPID DAMAGE ASSESSMENT AND GEOGRAPHIC INFORMATION SYSTEMS FOR EMERGENCY RESPONSE IN THE NORTHRIDGE EARTHQUAKE

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ABSTRACT

In response to the Northridge Earthquake of January 17, 1994, the Governor's Office of Emergency Services (OES) and EQE International utilized two new evolving technologies to gain a rapid understanding of the scope of the disaster. These were Geographic Information Systems (GIS), a sophisticated mapping and decision support technology and the Early Post Earthquake Damage Assessment Tool (EPEDAT), a GIS-based rapid damage assessment system which was in development at the time of the earthquake but provided useful information on probable losses and population impacts. The use of these new technologies is part of a multi-year effort to develop a real-time earthquake damage assessment capability and a natural outgrowth of advances in personal computing and mapping software. The Northridge Earthquake occurred at a time when both technological development and organizational changes within the Governor's Office of Emergency Services had made it possible to mobilize these technologies for emergency response decision making. Prior to the Northridge Earthquake, GIS had been applied to map the damage from the 1992 civil Unrest in Los Angeles and the Southern California Wild Fires of 1993. The Northridge Earthquake was the first urban disaster in which both GIS and rapid loss estimation techniques were applied in an integrated manner in emergency response and recovery.

KEYWORDS

Geographical Information Systems, GIS, damage assessment, loss estimation, EPEDAT, Northridge earthquake, OES, emergency response

INTRODUCTION

The Northridge Earthquake of January 17th, 1994 rattled more than the slumbering residents of the Los Angeles Basin in the early hours of the Monday Martin Luther King Jr. Holiday. To the Governor's Office of Emergency Services and many of the local jurisdictions, this event posed a real problem in understanding the magnitude of the disaster and the impacts to the urban environment. This task would be significantly eased through use of computational systems and the growing capabilities they offered to emergency response organizations. One of the primary areas of growth is the industry of Geographical Information Systems or GIS. The expanding storage, memory and computational abilities of desktop computers has allowed the software designers to greatly enhance the capability of their programs, and it is this capability which allowed OES to gain rapid understanding of the impact of Northridge over the entire region.

This paper will try to document how rapid damage assessment modeling in real time, combined with the use of GIS, helped the State of California, the Federal Emergency Management Agency (FEMA), and the City of Los Angeles deal with the Northridge Earthquake and provide relief to impacted citizens. Many of the tools used during the Northridge response were under development through existing contracts with OES. One of these projects was an effort to model the impact of a major earthquake along the southern San Andreas Fault, which evolved into the development by EQE International of real-time earthquake loss estimation software - the "Early Post-Earthquake Damage Assessment Tool" (EPEDAT). As luck would have it, even though the actual software program had not been completed at the time of the earthquake, the algorithms and loss models developed for the San Andreas study were available to assess potential damages caused by the Northridge event. EPEDAT databases include regional soil and fault data, building information assembled from County Assessor databases, and census and employment data. Following an earthquake, EPEDAT may be used to postulate a likely causative fault and associated rupture, estimate regional ground shaking in terms of Modified Mercalli Intensity, estimate damage to buildings and lifelines, and predict injuries, deaths, and shelter requirements. GIS, on the other hand was slowly being integrated into the thinking process of OES. By working on training exercises for the Nuclear Industry and helping map wildfire burn perimeters, GIS was making its mark. When OES responded to the Civil Unrest of 1992 in Los Angeles, GIS was used to map the locations of damaged structures and support recovery efforts. Not long after the Civil Unrest, came the wildland fires which caused extensive damage in Altadena, Malibu and Laguna Beach. These fires allowed the GIS group to expand, by placing an analyst in each of the fire centers. These centers provided assistance to the communities in their recovery efforts, and aided relief agencies in protecting these communities from further impacts like mudslides and flooding.

NORTHRIDGE RESPONSE EFFORTS

Immediately following the Northridge earthquake, the OES - GIS department consisted of a single laptop computer which was used to collect data and project initial damage assessment as scattered information flowed in. OES and FEMA were both scrambling to improve their grasp on what was occurring around the region, and gain control of the situation. It wasn't long before Consultants and GIS Distributors and manufacturers were brought in to assist the growing GIS department in gathering and dissemination information. These venders included MapInfo (through its local distributor Integrated Technologies Inc.), Arc Info (Environmental Systems Research Institute Inc.), and ATLAS*GIS (Strategic Mapping Incorporated). With time, MapInfo and Arc Info became the platforms of choice, and ITI and ESRI brought in equipment and people to support the response efforts. The earliest maps produced were based primarily on census data, and involved identifying areas where disaster assistance centers being set up by OES and FEMA might require interpreters. Other early maps attempted to catalogue damages to the freeway system and even displayed aerial photos of freeway damage. Mobile Disaster Assistance Centers, Salvation army and Red Cross Shelter sites and critical facility damages were all included in the early efforts.

While the stand-alone version of EPEDAT was not fully operational, the models were implemented to develop estimates of regional ground shaking intensities and associated losses. The ground shaking intensity map, shown in Figure 1, was transferred to OES-GIS for mapping and distribution within several days of the Northridge earthquake. This map, indicating ground shaking intensity throughout the impacted region, calculated at a zip code level, was used to define the general regional scope of the disaster and to brief the Governor and other state agency executives. The map, when combined with census information, was instrumental in determining where shelter sites and Disaster Assistance Centers would be set up. Department of Defense interpreters were requested in the areas which showed large populations of persons speaking languages other than English. OES and FEMA utilized the EPEDAT MMI map to "fast-track" the Federal Disaster Housing Assistance Program (DHAP). DHAP provides assistance to renters and homeowners if they are displaced from their homes due to disaster-related damages. Normally, applicants must have an inspection before assistance is granted, but following Northridge, checks were sent to all applicants residing in areas estimated to have suffered MMI VIII, IX or X according to the EPEDAT MMI map. Over 49,000 checks for over $138 million were mailed. Subsequent inspections revealed that over 90% of those receiving checks were, in fact, eligible for funding. This fast tracking of assistance took place within 7 days of the initial shock.

It should be noted that the estimated MMI map developed with the EPEDAT methodology differs from the official "observed" MMI map developed by the USGS for several reasons. The estimated MMI is calculated from a distance-attenuation relationship, while the observed MMI map is developed from mail surveys of individuals who experienced the earthquake. Although the precise boundaries of the areas of strongest ground shaking differ, the general vicinities are certainly consistent, identifying the strongest ground shaking in the San Fernando Valley as well as in other areas such as Santa Monica. The highest MMI on the estimated MMI map was larger than the highest observed MMI by one unit (MMI X vs. MMI IX). This is due, in part, to the fact that the Northridge earthquake was on a previously unidentified thrust fault. The EPEDAT model, based on previously available data, assumed a shallower source than actually occurred, resulting in slightly higher MMIs. The EPEDAT ground motion models have subsequently been revised to allow for deeper thrust-type events.

The EPEDAT loss models were run using only the earthquake's epicenter and magnitude as input, to estimate regional dollar losses caused by the earthquake. These estimates were used by OES to prepare the Preliminary Damage Assessment (PDA), a required part of the disaster declaration process prior to a Governor's request to the President. Beyond this initial dollar loss figure, more refined estimates were used in the calculation of the supplemental appropriation from Congress which ultimately reached $8.6 billion.

EARTHQUAKE DATABASE DEVELOPMENT FOR GIS

The true scope of a disaster is often not known for weeks or months. As part of the response process, actual damage data must be collected. This data collection function was performed by OES-GIS. Building damage data, as collected by local jurisdictions, is often in the form of post-earthquake building safety evaluation data. Following the 1987 Whittier Narrows earthquake, the need for a uniform safety inspection procedure was identified, and subsequently addressed by the Applied Technology Council (ATC). "Procedures for Post earthquake Safety Evaluation of Buildings" (ATC-20, 1989) made standardized inspection guidelines, as well as safety placards (red, yellow and green tags) widely available.

Within a few weeks of the initial shock, OES-GIS requested summaries of damage assessment surveys from the Jurisdictions in the declared counties. Once again blind luck would support the efforts put forth by the State's GIS lab. The City of Los Angeles had sent representatives up to San Francisco following the Loma Prieta Earthquake, where they learned what type of information that the State and Federal Government requested for disaster assistance. This knowledge enabled the City of Los Angeles to develop a system for the collection of the Building and Safety inspectors ATC-20 Rapid Damage Assessment forms. The City of Los Angeles also happened to be the jurisdiction which had the largest area affected by the earthquake. This provided the GIS unit with the unique opportunity to gather a large portion of the data electronically and then combine this dataset with others provided by the other jurisdictions.

OES had sent out the request for information with some fairly specific goals in mind, but found that not all of the jurisdictions were operating at the same level. Some jurisdictions could provide data electronically, but not in the same format which OES was using. Programs such as Q&A, Paradox, DBase and Lotus were used by many of the cities, and proved problematic for OES when the data arrived at the Disaster Field Office (DFO). There were, of course, cities which were not able to support the request for electronic data at all and OES had to manually input the data directly from copies of the ATC-20 forms. Even those cities which supplied the data electronically could not always supply the data in the format or with the fields OES requested. It was also necessary to try to glean additional information from the inspector's comments. EQE International assisted in the data collection process, by providing an engineer experienced with database development to review the data as it was received, categorize the data, and then translate the data into a consistent database format. Once again the data supplied by the City of Los Angeles, which comprised nearly 75% of the total damage data collected, was in a format requiring little effort to incorporate it into the master database, other than a quick review. The master building damage database had been designed by OES-GIS and EQE with the relational database programs of Access and Oracle in mind. This allowed the EQE Engineer to develop two tables; the first would have the unique location of each building and any specific data which relates to the physical geographic location of the facility, and the second table would document the inspection activities surrounding the structure. Many buildings were inspected after each major aftershock, and this information was provided to OES. Other times a building would receive a red (unsafe) tag and after some emergency repairs, the owner would ask for another inspection and receive a tag change. This "many to one" relationship (i.e., many inspection records for one building) can be easily handled by the relational database programs chosen.

Once all of the building inspection data had been reviewed and loaded into the Oracle database, the information was georeferenced to the Thomas Brothers Road Base. This allowed OES to map the damages that had been reported by the cities and get an understanding of the extent of the disaster. Figure 2 is one of the most popular maps produced by the GIS lab. This view of the basin with the Red/Yellow/Green tagging data and the shaded relief of the geography of the region provides a quick graphic view of the damages experienced by the population. This map was often used to enhance the quantity and quality of the data supplied by the jurisdictions. For example, one city supplied the inspection locations and some information on the damage, but did not include the tag color applied to the structure. The locations were georeferenced, colored black for "unknown tag" and shipped to the city's EOC and the Building and Safety contacts. The dark area of black dots surrounded by the colored sites of other jurisdictions plainly outlined the city boundary. Within a couple of days, OES received an updated file which contained the added field of tag to complete the data supplied. Figure 2 is the complete geocoded database as of March 31st, 1994 damage database at OES. Through the use of ArcInfo, OES was even able to develop a weighted average of the damage to determine locations of damage concentration. Figure 3 is the results of this effort which shows concentrations of damage based on an average of the tags for each grid cell and the focal mean value for the neighboring 15 cells. This whole effort of preparing the damage information georeferencing and mapping took three months from the actual earthquake.

The result of these data collection efforts was one of the most comprehensive digital databases ever developed to document earthquake impacts. These databases are likely to be the source of extensive earthquake engineering and impact research, and OES has made that data available. "The Northridge

Earthquake of January 17, 1994: Report of Data Collection and Analysis, Part A: Damage and Inventory Data" was published by OES, EQE and FEMA in May of 1995, with additional data made available in the Part B report (in press).

OTHER OES USES FOR GIS DATA

As the data was being compiled, other components of the State's response effort started to make use of the GIS lab as a resource. Projects like the SAC Joint Venture, which reviewed the steel building issue, utilized the capabilities and available data to assist some of their efforts. Members of SAC (Structural Engineers Association of California (SEAOC), Applied Technology Council (ATC), and California Universities for Research in Earthquake Engineering (CUREe)) brought data coverages, like spectral accelerations and velocities to OES, which supplied locations of all known steel buildings from the county assessor files. The members would then provide locations of inspected steel buildings with the identified damages for placement on the map. This information was eventually reviewed before the guidelines for steel building inspection and repair was issued. This project was funded by OES and FEMA.

One of the best uses of the OES-GIS lab was the Hazard Mitigation Grant Program for the Northridge Earthquake. The mitigation program includes schools, hospitals, and other public facilities. The GIS group was asked to locate all school campuses, district boundaries, and hospital locations. This was not an easy task. No single database was complete, and all databases were different enough in detail to make matching sites very difficult. In all it took the GIS team three months to develop a complete picture of the schools in the tri-county area and longer for the hospitals, clinics, and long term care facilities. This information was merged with the Public Assistance data to see how many of the facilities were receiving aid for damage and should be upgrading to the higher seismic standards with the PA funding.

CONCLUSIONS

Post-earthquake loss estimates, if developed rapidly, can provide useful information for emergency response purposes, as demonstrated in the Northridge earthquake. In addition, use of geographical information, census data, and an inventory of building structures can assist an emergency response organization to effectively predict potential high damage areas. With population demographics, assistance can be tailored to meet the local populations needs, or cultural response to an earthquake. Building inspectors can quickly respond to potential highly damaged areas first, freeing rescuers from areas of lighter shaking. Post-earthquake data collection, while problematic from the database managers viewpoint, can result in important databases by which researchers and practitioners can anticipate and possibly mitigate damage in future earthquake events.

References

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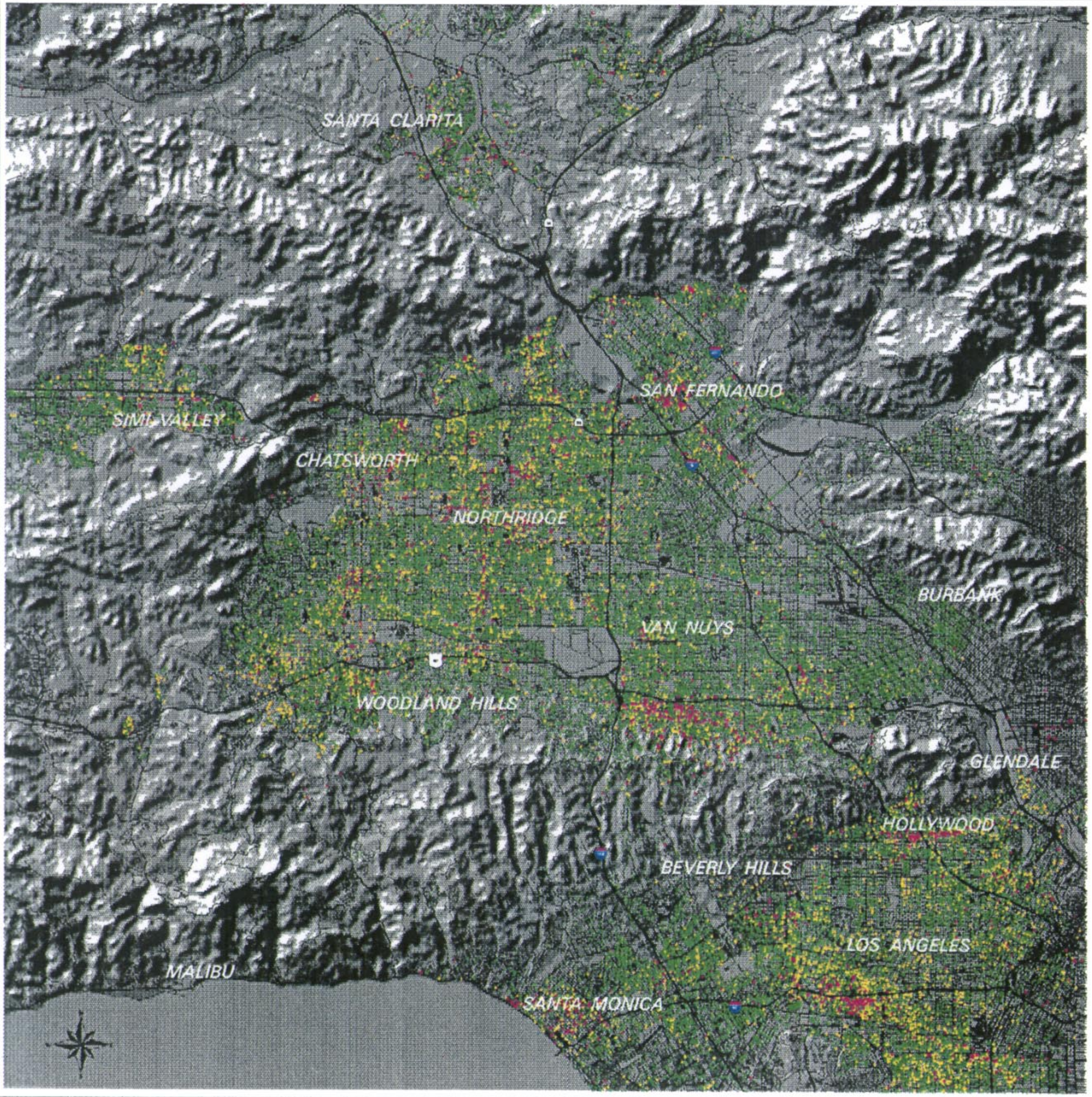
OES, EQE, FEMA (1995), The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis, Part A: Damage and Inventory Data, published by The Geographic Information Systems Group of the Governor's Office of Emergency Services, EQE International, and the Federal Emergency management Agency.

Figure 1



BUILDING AND SAFETY DAMAGE ASSESSMENT

Northridge Earthquake Disaster DR-1008

- ◆ UNSAFE - No Entry or Occupancy Allowed
- ◆ LIMITED ENTRY - Off Limits to Unauthorized Personnel
- ◆ INSPECTED - No Restriction on Use or Occupancy
- ◆ INSUFFICIENT DATA

Data Sources:
United States Geological Survey
- Elevation Data

Thomas Bros. Maps (c. 1994)
- Street Network
- Public Buildings

Various Municipal Jurisdictions
- Building Point Data

0 1 2 3 4 5 Miles

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Environmental Systems Research Institute (ESRI)

Figure 2

ESTIMATED MODIFIED MERCALLI INTENSITIES - LOS ANGELES AND VENTURA COUNTIES

Northridge Earthquake Disaster DR-1008

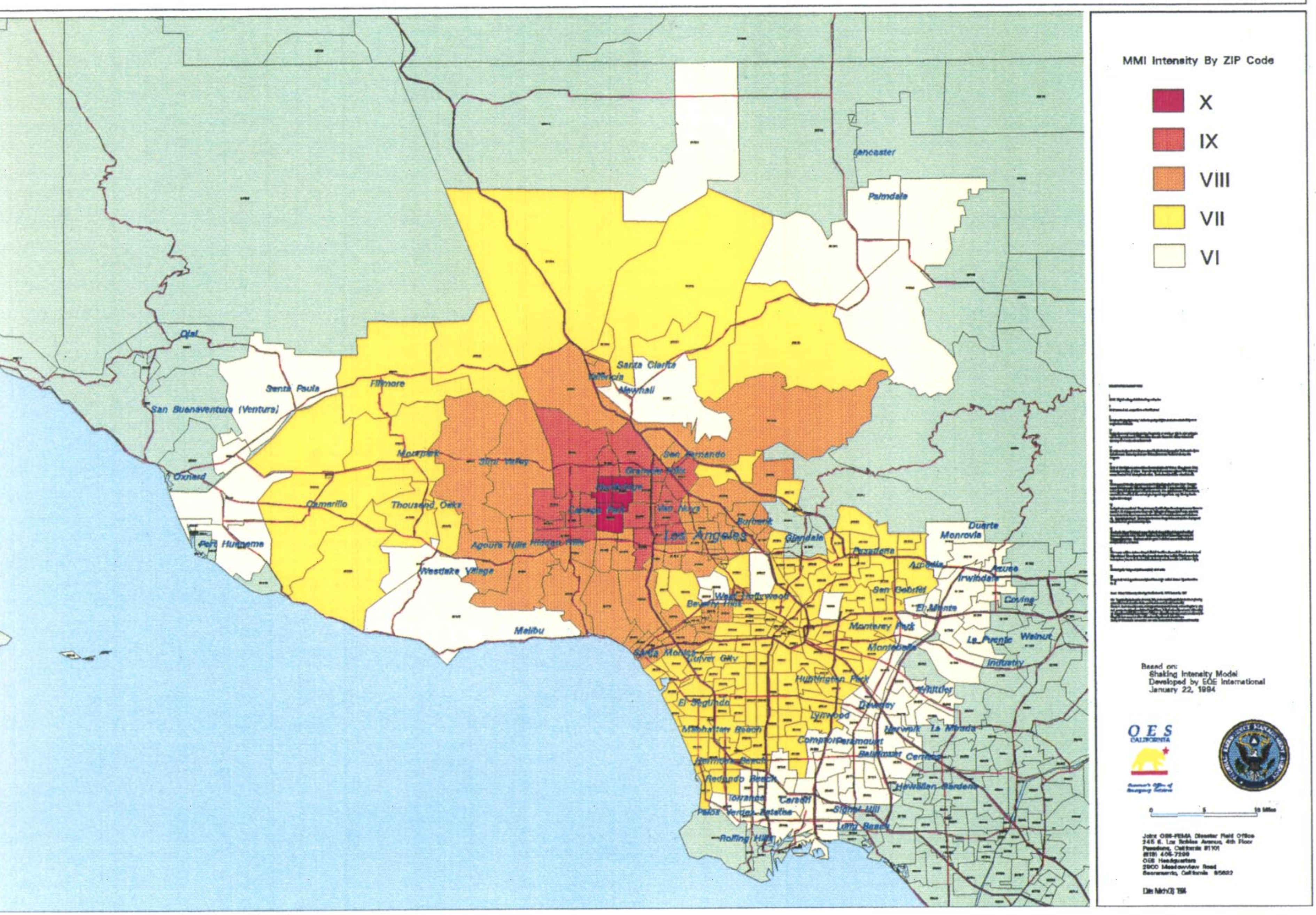

Figure 3

Concentrations of Building Damage and Liquefaction Susceptibility

Northridge Earthquake Disaster DR-1008