GIS-BASED HAZARD MAPPING AND LOSS ESTIMATION IN THE SAFETY ELEMENT OF THE GENERAL PLAN FOR RIVERSIDE COUNTY, CALIFORNIA

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ABSTRACT

We have compiled a GIS database of faults, earthquakes, engineering geology, slope instability, liquefaction, ground water, dam failure inundation, stream flooding, fire, wind, and subsidence for the County of Riverside. The hazard mapping provides overlays on which to conduct loss estimations related to existing infrastructure while attempting to minimize risk to new infrastructure. Eight scenario loss estimations associated with segments of the San Andreas, San Jacinto, and Elsinore faults were calculated for Riverside County using HAZUS^{TM}. Input parameters were adjusted based on our GIS database of soil, liquefaction and landslide mapping. The inventory exposure in Riverside County consists of 402,000 buildings valued at over $61 billion, with a population exposure of 1.2 million. Loss estimations for the eight scenario events varied from 1,100 to 10,500 casualties and $2.2 to $13.2 billion. The communicative value of event-specific loss estimation is important in recommending management and mitigation policies for local governments. Hazard mitigation policies are prioritized based on the results of hazard mapping and loss estimation and implemented through the Safety Element of the new General Plan. The Safety Element is a multi-hazard mitigation tool for land use planning guidance for local governments that can be more restrictive than the State's Seismic Hazards Mapping Act or the Alquist-Priolo Earthquake Fault Hazards Zoning Act. However, many local governments are operating with severely outdated Safety Elements that meet only the minimum requirements of California law.

Introduction

While many natural and man-made hazards have the potential to impact the County on a relatively frequent basis, the event with the greatest potential for loss of life, property and economic damages is an earthquake. This generalization is true for most of southern California and is due to the fact that earthquakes impact regions of significant areal extent, trigger many secondary effects such as landslides, fires and hazardous materials releases, and can overwhelm the ability of local jurisdictions to respond. Earthquake risk varies from very high in the western portion of the County, due to the presence of two of California's most active faults, the San Andreas and San Jacinto, to moderate in the eastern portion of the County that includes Blythe.

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Earthquake Hazards

For design purposes, a worst case scenario earthquake (maximum credible) for Riverside County is a magnitude M_W 7.9 based on the rupture of the entire southern segment of the San Andreas fault from Cajon Pass to the Salton Sea (this event last occurred in AD 1450 and 1680). While other scenarios will expose portions of the County to intense ground shaking locally as severe as the MCE, the MCE exposes much of the County to very high intensity ground shaking in a single event. Right-lateral horizontal ground displacements of up to twenty-five feet may occur along the fault scarps, intense ground shaking could last more than 60 seconds, and losses could be extensive.

Probable earthquake events, that is earthquakes that are likely to occur during the design life of most buildings, include an earthquake generated by the segments of the Elsinore, San Jacinto and San Andreas faults evaluated by the Working Group on California Earthquake Probabilities (1995) (Figure 1). Based on this segmentation, there are seven probable earthquakes that threaten Riverside County. The event with the greatest probability of occurrence in 30 years (43%) is a M_W 6.9 rupture of the San Jacinto Valley segment of the San Jacinto fault. The San Jacinto event is considered the maximum probable earthquake (MPE) for Riverside County.

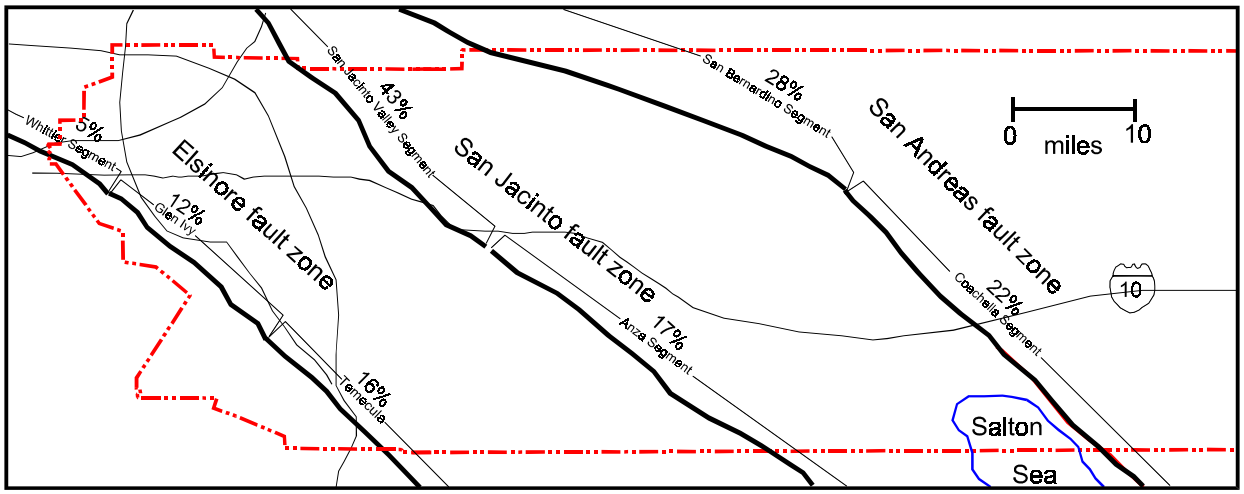

Figure 1. Thirty-year probabilities of large earthquakes on Riverside County fault segments (WGCEP, 1995).

GIS Hazard Mapping

Faulting

More than 4,300 faults and fault segments are included in the GIS database prepared for Riverside County. Data tables linked to the faults include the fault name, length, age and information on location (e.g. certain, concealed, queried, etc.). The fault locations are typically accurate to within 100 to 500 feet.

Soil Type

More than 60,000 polygons were assembled to create a digital "Engineering Geologic Map of Riverside County". The Uniform Building Code, as well as HAZUS, now outlines five soil types based on the average soil properties for the top 100 feet of the profile. We converted the digital geologic mapping to UBC soil types based on the following assumptions:

- S_A: Does not generally exist in California.
- S_B: Includes all igneous and metamorphic bedrock types.
- S_C: Includes all pre-Quaternary sedimentary rock types, as well as Pleistocene soils described as "indurated"
- S_D: Generally Pleistocene soils, or soils described as "moderately consolidated"
- S_E: Generally Holocene soils, or soils described as "unconsolidated" or "weakly consolidated"

Liquefaction

A detailed Liquefaction Susceptibility Map for Riverside County was produced at a 1:250,000 scale. The mapping combined a digital depth to ground water map and engineering geologic mapping in accordance with established recommendations (SCEC, 1999).

Landsliding

Seismically induced landsliding and rock falls can be expected to occur throughout the County in a major earthquake. As a major component of this project, we developed a digital landslide and slope instability map for Riverside County. The mapping is based on slope steepness, as well as engineering geology. The general procedures followed to create the Landslide and Slope Instability Map of Riverside County, included:

1. Creation of a slope map by producing a grid of the U. S. Geological Survey (USGS) Digital Elevation Model (DEM) for the County in Vertical Mapper© with a grid cell size of 60 meters on each side.
2. Creation of a grid map of the engineering geologic materials.
3. Queried both grid maps for areas that meet the parameters for slope instability and landslide susceptibility.

Earthquake Loss Estimations for Riverside County

The development of HAZUS™, a standardized methodology based on a geographic information system for earthquake loss estimation, is a project of the National Institute of Building Sciences, with funding from the Federal Emergency Management Agency (FEMA, 1999). These HAZUS loss estimations are based on current scientific and engineering knowledge, they are improved by mapping of soil type, liquefaction and landslide susceptibility as part of this study, and can be further improved by enhancing the building and infrastructure inventory in Riverside County.

Scenario Earthquakes

Eight scenario earthquakes were chosen to input into the HAZUS loss estimation (Table 1). Of these eight, additional detail are provided for the two events that represent the maximum probable earthquake (MPE) and the maximum credible earthquake (MCE) for Riverside County.

Table 1. Probable earthquake scenarios for Riverside County

Event		Mag (Mw)	30 yr. Prob.	Comments
Fault	**Segment**			
San Andreas	San Bernardino	7.3	28%	Very high intensity ground shaking throughout the San Bernardino Valley, including north central Riverside County.
San Andreas	Coachella	7.1	22%	Very high intensity ground shaking throughout the Coachella Valley, impacting desert resort communities and agriculture.
San Andreas	Southern	7.9	NA	Worst-case scenario for Riverside County involving simultaneous rupture of Coachella and San Bernardino segments. Paleoseismic evidence indicates this event may have occurred in 1450 and 1680.
San Jacinto	San Jacinto Valley	6.9	43%	Highest probability of occurrence of any southern California fault. Brought closer to failure as a result of stress field changes caused by the 1992 Landers earthquake.
San Jacinto	Anza Segment	7.2	17%	This event would be very destructive within the communities of Hemet and San Jacinto.
Elsinore	Temecula	6.8	16%	Has not produced any significant earthquakes in historic time.
Elsinore	Glen Ivy Segment	6.8	16%	Would be very destructive in the communities of Lake Elsinore, Murrieta, and Temecula.
Whittier	Whittier	6.8	5%	Produced the 1987 M 5.9 Whittier Narrows earthquake.

County of Riverside Inventory Data

The HAZUS inventory includes census tract data provided in the 1990 national census, as well as Dun and Bradstreet valuations for real estate compiled in 1994. The general building stock and population inventory data conform to census tract boundaries, whereas essential facilities and lifeline inventory are located by latitude and longitude. The HAZUS inventory data were developed at a national level and where specific data are lacking, statistical estimations were utilized. While the inventory is the best available for Riverside County, improvements to the inventory at a local level would improve the loss estimations.

- The geographical size of the County is 7,301 square miles and contains 124 census tracts. There are over 402 thousand households in the region with a total population of 1,170,400 people (1990 Census Bureau data).
- There are an estimated 402 thousand buildings in the region with a total building replacement value (excluding contents) of $61,138 billion dollars (1994 dollars). Approximately 98% of the buildings (and 82% of the building value) are associated with residential housing.

Estimated Losses Associated with Scenario Earthquakes

HAZUS loss estimations for Riverside County were run for the eight scenario earthquakes listed in Table 1. Relative representations of the loss estimates are presented on Figure 2 for all eight scenario events. Summaries of building damage, casualties, shelter requirements, and economic losses in Riverside County associated with the MCE and MPE are provided in Tables 2 through 5.

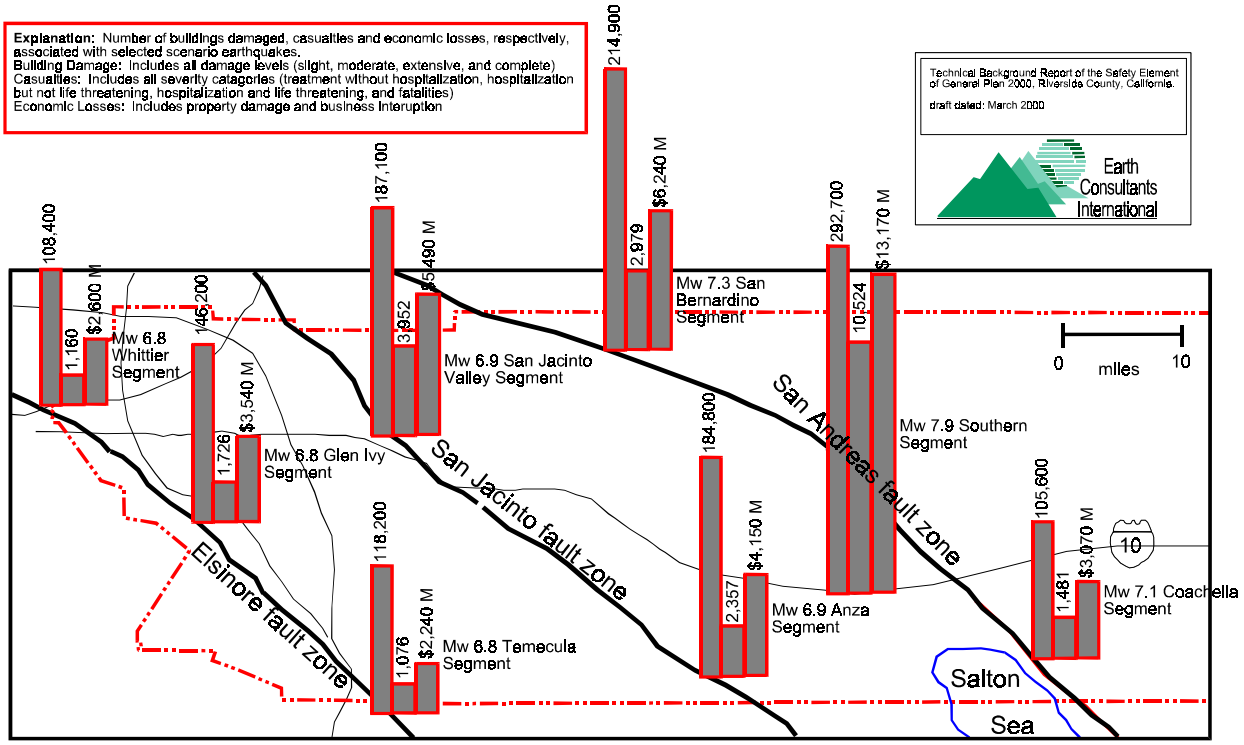

Figure 2. Relative estimated losses associated with scenario earthquakes. Bars for each event represent number of damaged buildings, casualties and economic losses, respectively.

Table 2. Number of Buildings Damaged

Scenario Event	Building Damage				Total
	Slight	*Moderate*	*Extensive*	*Complete*	
San Andreas-Southern Segment M_W 7.9	112,100	92,700	50,900	37,000	292,700
San Jacinto-San Jac. Valley Segment Mw 6.9	92,800	57,300	26,600	10,500	187,100

Table 3. Estimated Casualties

Scenario Event	Casualty Severity*				Total
	1	*2*	*3*	*4*	
San Andreas-Southern Segment M_W 7.9	8,431	1,570	383	140	10,524
San Jacinto-San Jac. Valley Segment Mw 6.9	3,226	573	107	46	3,952

*: Severity Definitions : 1) Medical treatment without hospitalization; 2) Hospitalization but not life threatening; 3) Hospitalization and life threatening; and 4) Fatalities.

Table 4. Estimated Shelter Requirements

Scenario Event	Estimates*	
	Displaced Households (no. of households)	**Short Term Shelter (no. of people)**
San Andreas-Southern Segment M_W 7.9 ***(MCE)***	26,620	19,900
San Jacinto-S.J. Valley Segment Mw 6.9 ***(MPE)***	9,860	7,410

*: Typically not all displaced persons require shelter. HAZUS uses demographics (ethnicity, income, ownership and age) to estimate the number of persons requiring short-term shelter.

Table 5. Estimated Economic Losses

Scenario Event	Economic Losses (millions)		
	Property Damage	**Business Interruption**	**Total**
San Andreas-Southern Segment M_W 7.9 ***(MCE)***	$9,790	$3,380	$13,170
San Jacinto-S.J. Valley Segment Mw 6.9 ***(MPE)***	$4,240	$1,250	$5,490

Summary

Detailed GIS mapping provides Riverside County with data to support hazard reduction policies, as well as improve loss estimations based on scenario earthquakes. In turn, these loss estimations further support mitigation through providing realistic emergency exercise guidelines, and support in policy recommendations. For example, the near source zone classification of the San Jacinto Valley segment of the San Jacinto fault as a Uniform Building Code "type B" fault (CDMG, 1998) may be inadequate based on projected loss estimations. In addition, this fault segment has the highest probability of generating a large earthquake in the next 30 years (43%; WGCEP, 1995) of any southern California fault. The San Jacinto's high slip rate (±12 mm/year), also supports reclassification at the local level as a "type A" seismic source. This reclassification would extend the near source zone an additional 5 kilometers, and may mitigate the potential for building damage in portions of the cities of Riverside, Moreno Valley and Perris.

References

California Division of Mines and Geology (CDMG), 1998, Maps of Known Active Near-Source Zones in California and Adjacent Potions of Nevada, to be used with the 1997 Uniform Building Code: published by the International Conference of Building Officials.

Federal Emergency Management Agency, 1999, HAZUS, FEMA's Tool for Estimating Potential Losses from Natural Disasters: Western Region, Build 257, October, 1999.

Southern California Earthquake Center (SCEC), 1999, Recommended procedures for implementation of DMG SP117 Guidelines for Evaluating and Mitigating Seismic Hazards in California - Liquefaction Hazards: Martin, G.R., and Lew, M, (editors).

Working Group on California Earthquake Probabilities (WGCEP), 1995, Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, v. 85, no. 2, pp. 379-439.