UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Earthquake Hazards in the Pacific Northwest of the United States

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TECHNIQUES FOR REDUCING EARTHQUAKE HAZARDS-- AN INTRODUCTION

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Open-File Report 91-441-L

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1991

Foreword

This paper is one of a series dealing with earthquake hazards of the Pacific Northwest, primarily in western Oregon and western Washington. This research represents the efforts of U.S. Geological Survey, university, and industry scientists in response to the Survey initiatives under the National Earthquake Hazards Reduction Program. Subject to Director's approval, these papers will appear collectively as U.S. Geological Survey Professional Paper 1560, tentatively titled "Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest." The U.S. Geological Survey Open-File series will serve as a preprint for the Professional Paper chapters that the editors and authors believe require early release. A single Open-File will also be published that includes only the abstracts of those papers not included in the pre-release. The papers to be included in the Professional Paper are:

Introduction

Rogers, A.M., Walsh, T.J., Kockelman, W.J., and Priest, G.R., "Earthquake hazards in the Pacific Northwest: An overview

Tectonic Setting

Paleoseismicity

Adams, John, "Great earthquakes recorded by turbidites off the Oregon-Washington margin"

Atwater, B.F., "Coastal evidence for great earthquakes in western Washington"

Nelson, A.R., and Personius, S. F., "The potential for great earthquakes in Oregon and Washington: An overview of recent coastal geologic studies and their bearing on segmentation of Holocene ruptures, central Cascadia subduction zone"

Peterson, C. D., and Darienzo, M. E., "Discrimination of climatic, oceanic, and tectonic forcing of marsh burial events from Alsea Bay, Oregon, U.S.A."

Tectonics/Geophysics

Goldfinger, C., Kulm, L.D., Yeats, R.S., Appelgate, B., MacKay, M., and Cochrane, G., "Active strike-slip faulting and folding in the Cascadia plate boundary and forearc, in central and northern Oregon"

Ma, Li, Crosson, R.S., and Ludwin, R.S., "Focal mechanisms of western Washington earthquakes and their relationship to regional tectonic stress"

Snavely, P. D., Jr., and Wells, R.E., "Cenozoic evolution of the continental margin of Oregon and Washington"

Weaver, C. S., and Shedlock, K. M., "Estimates of seismic source regions from considerations of the earthquake distribution and regional tectonics"

Yeats, R.S., Graven, E.P., Werner, K.S., Goldfinger, C., and Popowski, T.A., "Tectonic setting of the Willamette Valley, Oregon"

Earthquake Hazards

Ground Motion Prediction

Cohee, B.P., Sommerville, P.G., and Abrahamson, N.A., "Ground motions from simulated M_W=8 Cascadia earthquakes"

King, K.W., Carver, D.L., Williams, R.A., and Worley, D.M., "Site response studies in west and south Seattle, Washington"

Madin, I. P., "Earthquake-hazard geology maps of the Portland metropolitan area, Oregon"

Silva, W.J., Wong, I.G., and Darragh, R.B., "Engineering characterization of strong ground motions with applications to the Pacific Northwest"

Ground Failure

Chleborad, A. F., and Schuster, R. L., "Earthquake-induced ground failure associated with the April 13, 1949, and April 29, 1963, Puget Sound area, Washington, earthquakes"

Grant, W. P., Perkins, W. J., and Youd, L., "Liquefaction susceptibility maps for Seattle, Washington North and South Quadrangles

Earthquake Risk Assessment

Wang, Leon R.L., Wang, Joyce C.C., and Ishibashi, Isao, "GIS applications in seismic loss estimation model for Portland, Oregon water and sewer systems"

Implementation

Kockelman, W. J., "Techniques for reducing earthquake hazards--An introduction"

Booth, D.B., and Bethel, J.P., "Approaches for seismic hazard mitigation by local governments--An example from King County, Washington"

May, P.J., "Earthquake risk reduction prospects for the Puget Sound and Portland Areas"

Perkins, J.B., and Moy, K.K., "Liability for earthquake hazards or losses and its impacts on Washington's cities and counties"

Preuss, Jane, and Hebenstreit, G. T., "Integrated hazard assessment for a coastal community: Grays Harbor"

Contents

List of Tables

Illustrations

ABSTRACT

Many techniques are available for reducing earthquake hazards; 36 are identified in this chapter. Six of these are described with examples--redevelopment plans, regulatory zones, nonstructural building components, public information, unreinforced masonry buildings, and loss estimates. An overview of these techniques is useful to planners who implement hazard-reduction programs, to engineers who serve as advisors to local or state governments, and to decisionmakers who select the most appropriate technique for a given situation. Prerequisites for the successful use of these techniques are adequate and reliable scientific and engineering information, translation of such information for use by nontechnical users, and effective transfer of the translated information to those who will, or are required to, use it.

INTRODUCTION

Numerous techniques for reducing earthquake hazards are available to planners, engineers, and decisionmakers. Some of these techniques, such as public acquisition of hazardous areas, are well-known to the planning profession. Others, such as design of resistant structures, are commonly used by engineers. Still others, such as warning systems and emergency preparedness, are obvious and practical, but require maintenance and persistence in their implementation.

To give the reader an overview, examples of various techniques are shown in list 1. These techniques are divided into six groups related to specific objectives; however, they can also be grouped in other ways, for example, chronologically:

- Pre-event mitigation techniques, which may take 1 to 20 yr
- Preparedness measures, which may take 1 to 20 wk
- Response during and immediately after an event
- Recovery operations after an event, which may take 1 to 20 wk
- Post-event reconstruction activities, which may take 1 to 20 yr

These estimated time periods vary depending upon the postulated or actual size of the earthquake, its damage, and the resources available to a state, its communities, its corporations, and its citizens.

The specific objectives of these techniques (list 1) are to create an: awareness of, avoidance of, resistance to, response to, or recovery from, the effects of the earthquake phenomena on people and their land uses, structures, and activities. The general goal of these objectives is to reduce human casualties, property damage, and socioeconomic interruptions. Many of the reduction techniques are complex, interconnected, and require special skills--legal, financial, legislative, design, economic, communicative, educational, political, and engineering.

Many of the hazard reduction techniques have been discussed and illustrated by Blair and Spangle (1979), Kockelman and Brabb (1979), Brown and Kockelman (1983), Kockelman (1985, 1986), Jochim and others (1988), Mader and Blair-Tyler (1988), Blair-Tyler and Gregory (1988), and the United Nations Office of the Disaster Relief Coordinator (Lohman and others, 1988).

List 1. EXAMPLES OF VARIOUS TECHNIQUES FOR REDUCING EARTHQUAKE HAZARDS

Incorporating hazard information into studies and plans

- Community-facilities inventories and plans
- Economic-development analysis and plans
- Emergency and public-safety plans
- Land-use and transportation inventories and plans
- *Redevelopment plans (pre-event and post-disaster)
- Utility inventories and plans

Regulating development

- *Creating special hazard-reduction zones and regulations
- Enacting building and grading ordinances
- Enacting subdivision ordinances
- Requiring engineering, geologic, and seismologic reports
- Requiring investigations in hazardous areas
- Reviewing annexation, project, and rezoning applications

Siting, designing, and constructing safe structures

- Evaluating specific sites for hazards
- Reconstructing after a disaster
- *Securing nonstructural building components and contents
- Selecting the most resistant building system and configuration
- Siting and designing critical facilities
- Training design professionals and building inspectors

Discouraging new development in hazardous areas

- Adopting utility and public-facility service-area policies
- Clarifying the liability of developers and government officials
- Creating financial incentives and disincentives
- *Informing and educating the public
- Posting public signs that warn of potential hazards
- Requiring nonsubsidized insurance related to level of hazard

Strengthening, converting, or removing unsafe structures

- Condemning and demolishing unsafe structures
- Reducing land-use intensities or building occupancies
- Relocating community facilities and utilities
- Repairing unsafe dams or lowering their impoundments
- Retrofitting bridges and overpasses
- *Strengthening unreinforced masonry buildings

Preparing for and responding to emergencies and disasters

- Conducting emergency or disaster training exercises
- *Estimating casualties, damage, and interruptions
- Initiating community and corporate education programs
- Operating monitoring, warning, and evacuation systems
- Preparing emergency response and recovery plans
- Providing for damage inspection, repair, and recovery

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* Technique described and illustrated in this chapter.

Prerequisite to the use of these reduction techniques are scientific and engineering studies. Such studies are vital, because in the words of a former U.S. Geological Survey director, Walter C. Mendenhall: "There can be no applied science unless there is science to apply." It has been my experience that it is not prudent for urban planners to develop land-use regulations, civil engineers to design structures, and lenders and public works directors to adopt policies reducing earthquake hazards without reliable scientific and engineering assessments.

Six earthquake-hazard reduction techniques were selected as examples for this chapter:

- Preparing redevelopment plans
- Creating regulatory zones
- Securing nonstructural building components
- Informing the public
- Strengthening unreinforced masonry buildings
- Estimating casualties, damage, and interruptions

These six techniques are briefly discussed and generally illustrated for nontechnical readers. The references cited for each technique discussed will provide both scholars and practitioners with more details and examples.

PREPARING REDEVELOPMENT PLANS

Incorporating earthquake-hazard information into plans for the development or redevelopment of a community's land use, housing, transportation, and other public facilities is a common natural-hazard reduction technique. One of these plans is the redevelopment plan. Most states authorize the creation of public redevelopment agencies which provide for: the preparation and adoption of redevelopment plans; the acquisition, clearance, disposal, reconstruction, and rehabilitation of blighted (including damaged) areas; and the relocation of those persons displaced by the project. These redevelopment agencies usually are empowered to issue bonds, receive part of the taxes levied on property in the project, and use grants or loans available under various state and federal programs. Redevelopment plans may be divided into three categories; namely, those which incorporate:

- Damaged areas into a redevelopment plan that had been created prior to a damaging earthquake.
- Vulnerable structures (identified prior to an earthquake) into a redevelopment plan.
- Damaged areas into a redevelopment plan that is being created after an earthquake.

Santa Rosa, a city of about 50,000 people, illustrates the first category. It was hit within two hours by two earthquakes in 1969, damaging numerous old unreinforced masonry buildings. Mader and others (1980, p. C1 to C15) report that:

> In 1961, Santa Rosa embarked on a redevelopment project covering part of the downtown area. Just prior to the earthquakes, the city had adopted a central business district 6plan which covered an area adjacent to the redevelopment area. After the earthquakes, this area, with a high percentage of damaged buildings, was added to the original redevelopment area.

The time and effort to get the revised redevelopment project funded and underway after the earthquake was significantly less because of the existence of an up-to-date plan (fig. 1) adopted prior to the earthquake.

Spangle and others (1987, app. A) describe the second category--vulnerable structures identified prior to an earthquake. It is a new technique called "pre-earthquake planning for post-earthquake rebuilding." It includes four preevent activities: evaluate vulnerability to damage; organize for preparedness and response; mitigate hazards; and plan for post-earthquake response. They comment that it is possible to develop damage estimates sufficiently accurate for pre-earthquake programming for post-earthquake recovery activities and to define the nature of the post-earthquake recovery organization needed.

The Whittier City Redevelopment Agency (1987) adopted a plan that represents the third category--redevelopment plans created after an earthquake. The plan provides for redevelopment powers to be used for projects to maintain, repair, restore, demolish, or replace property or facilities damaged or destroyed as a result of the 1987 earthquake. The earthquake damage in their city exceeded 70 million in 1987 dollars. Preparing and implementing redevelopment plans that recognize and reduce earthquake hazards is unusually important because reconstruction commonly takes place in the same hazardous areas after an earthquake. Youd and others (1978, p. 111), for example, observed that, after the San Fernando earthquake, "... buildings had been repaired, new buildings have been built, and a freeway interchange has been constructed across the trace of the 1971 fault rupture."

CREATING REGULATORY ZONES

Various types of land-use and land-development regulations to reduce earthquake hazards are available to state and local governments. Controlling use and development by regulatory zones can be one of the most economical and effective means available to government agencies. The regulations can be used to reduce earthquake hazards such as surface-fault rupture, ground shaking, liquefaction, landslides, and tsunamis. Such regulations may be divided into four categories:

- Requiring site investigations and building setbacks.
- Reducing the density of development or the number of occupants.
- Permitting only less vulnerable land uses and land developments.
- Requiring special seismic design and construction standards.

The first category can be illustrated by the Alquist-Priolo Special Studies Zones Act enacted by the California Legislature (1972). The Act provides for public safety by restricting development near or over the surface traces of active faults (fig. 2). In addition, the act provides for geologic reports, approval of projects by cities and counties, and the charging of reasonable fees for administrative costs. The State Geologist delineates appropriately wide zones which include "all potentially and recently active traces" of faults that "he deems sufficiently active and well-defined to constitute a potential hazard to structures from surface faulting or fault creep" (Hart, 1988, app. A).

Cities and counties must require, before approval of a project in these zones, "a geologic report defining and delineating any hazard of surface fault rupture." The legislature defines "project" to include structures for human occupancy and any subdivision which contemplates the eventual construction of structures for human occupancy. The legislature exempts single-family wood-frame buildings (including mobile homes) not exceeding two stories when not part of a development of four or more dwellings. The approval of a project must be in accord with the policies and criteria established by the California Mining and Geology Board. The board (Hart, 1988, app. B) prohibits a project across the trace of an active fault; requires a geologic report if a project lies within 15 m (50 ft) of an active fault; and requires a registered geologist retained by the city or county to evaluate such reports. The act allows cities and counties to establish more restrictive policies and criteria. Some local jurisdictions, such as the Portola Valley Town Council (1973), require multi-family buildings to be set back 40 m (125 ft) or more from fault traces.

The San Mateo County Board of Supervisors (1973) is using the second category--reducing the density of development. It is a resource-management zoning district that also carries out the objectives and policies of their open-space and resource-conservation plans. The district regulations limit the number of dwellings in zones with a surface-fault rupture hazard, flood hazard, or unstable slopes to one unit per 16 hectares (40 acres) and require geologic site investigations to ensure that the reduced development is located in nonhazardous areas (fig. 3). The lower net number of dwellings permitted may then be clustered at a higher density in the nonhazardous areas.

An example of the third category--permitting only less vulnerable land uses--may be seen in Colorado where geologic hazards have been declared by the state legislature to be matters of state interest. To assist communities in designing land-use regulations, the Colorado Geological Survey prepared model geologic-hazard area control regulations for adoption by local governments. The model regulations permit only the following "open" uses in areas designated geologically hazardous: (1) agricultural uses such as general farming, grazing, truck farming, forestry, sod farming, and wild-crop harvesting; (2) industrial-commercial uses such as loading areas, parking areas not requiring extensive grading or impervious paving, and storage yards for equipment or machinery easily moved or not subject to geologic-hazard damage; and (3) public and private recreational uses not requiring permanent structures designed for human habitation such as parks, natural swimming areas, golf courses, driving ranges, picnic grounds, wildlife and nature preserves, game farms, shooting preserves, target ranges, trap and skeet ranges, and hunting, fishing, skiing, and hiking areas, if such uses do not cause concentrations of people.

The fourth category is well illustrated by Redwood City Council (1974, 1977) ordinances that require special seismic design and construction standards. These standards supplement those recommended by the International Conference of Building Officials for structures in seismic zone 4 under the Uniform Building Code--the code adopted by the city as its own building code.

This ordinance is consistent with the city's initial Seismic Safety Element (Redwood City Planning Department, 1974), which had placed the mud around the margins of the San Francisco Bay in a moderately-high risk zone and recommended that the Uniform Building Code be reviewed and amended as "frequently as may be prudent." The supplemental standards called for in the city's ordinance relate to special foundation-design criteria, design provisions for greater lateral force, foundation systems to resist settlement, wood-frame sheathing, moment-resisting frames, response spectrum, reinforced-masonry construction, elements of structural redundancy, and reinforcement of structural members. These standards apply only to those lands within the city that are underlain by bay mud, as shown on a map adopted by reference in the ordinance (fig. 4).

SECURING NONSTRUCTURAL BUILDING COMPONENTS

Proper siting, design, and construction of structures are well-known techniques to reduce earthquake casualties and damage but often the contents and other nonstructural components of buildings are overlooked. People have been injured by falling light fixtures, flying glass, overturning shelves, and spilled chemicals. The Federal Emergency Management Agency (1981, table 2) estimates that one-third of the property lost in future earthquakes will be attributed to building contents. Such contents are only one part of the nonstructural components of buildings.

Nonstructural damage is caused by object inertia or structure distortion. For example, if an office computer is shaken, only friction will restrain it from sliding towards its user. As a structure bends or distorts, its windows, partitions, and other items set in the structure are stressed, causing them to shatter, crack, or spring out of place. Numerous protective measures are available, including:

- Bolting down sharp or heavy office equipment and fixtures.
- Tying artwork to the walls.
- Connecting filing cabinets together at their tops and to a wall.
- Zigzagging free-standing, movable partitions.

- Installing locks on cupboards.
- Boxing large containers that contain hazardous chemicals.
- Strapping hot-water heaters to wall studs.

An excellent guidebook on reducing the risk of nonstructural earthquake damage was prepared by Reitherman (1983). He describes typical conditions found in office, retail, and government buildings. Measures are suggested for restraining over 20 nonstructural building components, such as office machines, electrical equipment, file cabinets, built-in partitions, suspended ceilings, exterior ornamentation, elevators, piping, stairways, and parapets. Each component is rated for existing and upgraded vulnerability for life-safety hazards, percent of replacement-value damaged, and post-earthquake outages for three levels of shaking intensity (fig. 5).

A second guidebook focuses on procedures for reducing nonstructural hazards in schools. This guidebook was issued by the Washington State Superintendent of Public Instruction (Noson, 1989) and contains drawings of methods for securing hazardous objects commonly found in schools. The objects include ceiling panels, chemicals, doors, exterior chimneys, exterior masonry, parapets, furniture, file cabinets, windows, mirrors, skylights, heaters, light fixtures, partitions, and water heaters. A general estimate of the earthquake risk for each object and the cost to secure each are provided. In addition, checklists for school administrators and custodians are included for both interior hazards--ceilings, floors, walls, boiler rooms, cafeterias, halls, stairways, laboratories--and exterior hazards--chimneys, ornamentations, and parapets.

The application of such guidebooks to another type of public building may be seen in the city of Mountain View. Blair-Tyler and Gregory (1988, p. 19) observed that the city had consultants prepare a room-by-room inventory of nonstructural hazards in the Emergency Operations Center--an alternate City Hall which must function after an earthquake. They report that:

> Communications equipment was braced and interior glass is being replaced with safety glass or covered with a safety film. The City's maintenance staff is providing the estimated 320 man-hours to complete the nonstructural work during the next year. Any structural strengthening will be done by an outside contractor. Information gained from this experience will be used to reduce nonstructural hazards in the design of Mountain View's new Library and City Hall.

INFORMING THE PUBLIC

The fourth selected earthquake-hazard reduction technique involves public information programs which are essential for bringing earthquake-hazard information to the attention of the public. Both pre-event and post-event hazard-reduction programs depend on the understanding and support of an informed public. Responsible developers and prudent citizens, when told of earthquake hazards, may not wish to risk property losses or expose their clients or families to the danger and trauma. Preparing, announcing, and disseminating information on earthquake damage, risk, and hazard-reduction techniques can be accomplished through numerous methods. Examples are cited in lists 2 and 3.

List 2. EXAMPLES OF TRANSFER TECHNIQUES FOR INFORMING THE PUBLIC

General, Introductory, and Index Materials

Washington State Earthquake Hazards by Noson, Qamar, and Thorsen (1988)
Facing Geologic and Hydrologic Hazards by Hays (1981)
Home Guide Section on How a House Withstands an Earthquake by Kerch (1988)
Getting Ready for a Big Quake by Sunset Magazine (1982)
Bibliography and Index to Seismic Hazards of Western Washington compiled by Manson (1988)
Policy Recommendations by the Washington State Seismic Safety Council (1986)

Serial Publications

Oregon Geology by Oregon State Department of Geology and Mineral Industries (bimonthly)
Earthquake Hazard Reduction Series by the Federal Emergency Management Agency (see list 3)
Earthquakes and Volcanoes (formerly Earthquake Information Bulletin) by Spall (1971 to present)
Washington Geologic Newsletter by Washington State Division of Geology and Earth Resources (quarterly)
Wasatch Front Forum by Hassibe (1984-1986) and Jarva (1987-present)

Guidebooks and Guidelines

Geologic Principles for Prudent Land Use by Brown and Kockelman (1983)
Earthquake Advisor's Handbook for Wood-Frame Houses by the University of California Center for Planning and Development Research (1982)
Reducing Earthquake Risks for Planners by Jaffe and others (1981)
Preparing a Safety Element of the City and County General Plan by Mintier (1987, p. 146-153)
Steps to Earthquake Safety for Local Governments by Mader and Blair-Tyler (1988)
Landslide Loss Reduction Guide for State and Local Government Planning by Wold and Jochim (1989)

Conferences and Workshops

Governor's Conference on Geologic Hazards by the Utah Geological and Mineral Survey (1983)
3rd Annual Workshop on "Earthquake Hazards in the Puget Sound, Portland Area" by Hays (1989)
Workshop on "Evaluation of Earthquake Hazards and Risk in the Puget Sound and Portland Areas" by Hays (1988)
Workshop on Future Directions in Evaluating Earthquake Hazards of Southern California by Brown, Kockelman, and Ziony (1986)
Third International Earthquake Microzonation Conference by Sherif (1982, particularly sessions 3, 6, and 10)

Outreach Programs

Circuit-Rider Geologist in the State of Washington by Thorsen (1981)
Planning, Reviewing, and Enforcing by City and County Geologists by McCalpin (1985) and Christenson (1988)
Advisory Services Unit of the California Division of Mines and Geology by Amimoto (1980)
Educational, Advisory and Review Services by the Southeastern Wisconsin Regional Planning Commission (1968, 1987)
Earth-Science Information Dissemination Activities of the U.S Geological Survey by Information Systems Council's Task Force on Long-Range Goals of USGS Information Dissemination (1987)
School Earthquake Safety and Education Project in the Puget Sound area by Martens (1988)

Discussions of Adopted Reduction Techniques

Anticipating Earthquakes--Risk Reduction Policies and Practices in the Puget Sound and Portland Areas by May (1989)
School Earthquake Emergency Planning by Noson and Martens (1987)
Case Studies on Strengthening Hazardous Buildings by the Bay Area Regional Earthquake Preparedness Project (1988)
Using Earth-Science Information for Earthquake Hazard Reduction in the Los Angeles Region by Kockelman (1985)
Putting Seismic Safety Policies to Work by Blair-Tyler and Gregory (1988)
Examples of Seismic Zonation in the San Francisco Bay Region by Kockelman and Brabb (1979)

List 3. EARTHQUAKE HAZARDS REDUCTION SERIES[1]

Pub. No.	Title	EHRS No.
FEMA 67	Earthquake Public Information Materials: An Annotated Bibliography	EHRS 8
FEMA 68	Earthquake Insurance: A Public Policy Dilemma	EHRS 7
FEMA 69	Pilot Project for Earthquake Hazard Assessment	EHRS 6
FEMA 70	Earthquake Preparedness Information for People with Disabilities	EHRS 5
FEMA 71	Comprehensive Earthquake Preparedness Planning Guidelines: Corporate	EHRS 4
FEMA 72	Comprehensive Earthquake Preparedness Planning Guidelines: County	EHRS 3
FEMA 73	Comprehensive Earthquake Preparedness Planning Guidelines: City	EHRS 2
FEMA 74	Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide	EHRS 1
FEMA 83	Societal Implications: A Community Handbook	EHRS 13
FEMA 84	Societal Implications: Selected Readings	EHRS 14
FEMA 87	Guidelines for Local Small Businesses	EHRS 12
FEMA 90	An Action Plan for Reducing Earthquake Hazards of Existing Buildings	EHRS 16
FEMA 91	Proceedings: Workshop on Reducing Seismic Hazards of Existing Buildings	EHRS 15
FEMA 95	NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings Part 1: Provisions and Maps (1985 Edition)	EHRS 17
FEMA 96	NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings Part II: Commentary (1985 Edition)	EHRS 18
FEMA 98	Guidelines for Preparing Code Changes Based on the NEHRP Recommended Provisions	EHRS 21
FEMA 99	Improving Seismic Safety of New Buildings: A Nontechnical Explanation of NEHRP Provisions	EHRS 20
L-143	Preparedness in Apartments and Mobile Homes	EHRS 22
FEMA 111	A guide to Marketing Earthquake Preparedness: Community Campaigns that Get Results	EHRS 23
FEMA 112	Marketing Earthquake Preparedness: Community Campaigns that Get Results	EHRS 24
FEMA 135	Abatement of Seismic Hazards to Lifelines: Water and Sewer	EHRS 26
FEMA 136	Abatement of Seismic Hazards to Lifelines: Transportation	EHRS 27
FEMA 137	Abatement of Seismic Hazards to Lifelines: Communications	EHRS 28
FEMA 138	Abatement of Seismic Hazards to Lifelines: Power	EHRS 29
FEMA 139	Abatement of Seismic Hazards to Lifelines: Gas and Liquid Fuels	EHRS 30
FEMA 140	Guide to Application of the NEHRP Recommended Provisions in Earthquake-Resistant Building Design	EHRS 25
FEMA 142	Abatement of Seismic Hazards to Lifelines: An Action Plan	EHRS 32
FEMA 143	Abatement of Seismic Hazards to Lifelines: Papers on Political, Economic, Social, Legal, and Regulatory Issues	EHRS 31
FEMA 146	Comprehensive Earthquake Preparedness Planning Guidelines: Large City	EHRS 33
FEMA 149	Seismic Considerations: Elementary and Secondary Schools	EHRS 34
FEMA 150	Seismic Considerations: Health Care Facilities	EHRS 35
FEMA 151	Seismic Considerations: Hotels and Motels	EHRS 36
FEMA 152	Seismic Considerations: Apartment Buildings	EHRS 37
FEMA 153	Seismic Considerations: Office Buildings	EHRS 38
FEMA 154	Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook	EHRS 41
FEMA 155	Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation	EHRS 42
FEMA 156	Typical Costs for Seismic Rehabilitation of Existing Buildings, Volume I--Summary	EHRS 39
FEMA 157	Typical Costs for Seismic Rehabilitation of Existing Buildings, Volume II--Supporting Documentation	EHRS 40
FEMA 158	Earthquake Damaged Buildings: An Overview of Heavy Debris and Victim Extrication	EHRS 43
FEMA 162	Differences between the 1985 and 1988 Editions of the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings	EHRS 44
FEMA 172	Techniques for Seismically Rehabilitating Existing Buildings (Preliminary)	EHRS 49
FEMA 173	Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings: Supporting Report	EHRS 46

List 3 . EARTHQUAKE HAZARDS REDUCTION SERIES (continued)

Pub. No.	Title	EHRS No.
FEMA 174	Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings: A Handbook	EHRS 45
FEMA 176	Estimating Losses from Future Earthquakes--Panel Report (A Non-Technical Summary)	EHRS 50
FEMA 177	Estimating Losses from Future Earthquakes (Panel Report and Technical Background)	EHRS 51
FEMA 178	A Handbook for Seismic Evaluation of Existing Buildings (Preliminary)	EHRS 47

The publications are free of charge; copies may be requested by writing to:
Federal Emergency Management Agency, P.O. Box 70274, Washington, D.C. 20024

1/ Modified from an Earthquake Hazards Reduction Series list prepared by the Federal Emergency Management Agency (July 1989).

STRENGTHENING UNREINFORCED MASONRY BUILDINGS

Numerous techniques for strengthening, converting, or removing unsafe structures are available to state and local governments. One of these--strengthening unreinforced masonry buildings--has been used by several communities. Its first phase--identification of unsafe buildings by cities and counties--has begun for the state of California.

These unsafe structures include unreinforced masonry bearing-wall buildings and steel- and concrete-frame buildings with infill walls that are of unreinforced masonry. According to the California Seismic Safety Commission (1987, p. 2), these structures typically have four areas of weakness:

- Masonry walls, lacking reinforcing, do not have resistance to earthquake shaking without degrading, sometimes leading to collapse.
- The practice of not structurally tying the walls to the roof and floors can allow excessive movements in the walls, which may lead to collapse.
- Ground floors with open fronts and little crosswise bracing may allow excessive movement and twisting motions, damaging the building.
- Unbraced parapets may fall into the street.

An ordinance adopted by the Los Angeles City Council (1981) provides procedures and standards for identifying and classifying buildings having unreinforced masonry bearing walls; these procedures and standards are based on a building's present use and occupancy (fig. 6). Priorities, time periods, and standards are also established under which buildings are required to be structurally analyzed and anchored. Where analysis determines deficiencies, the ordinance requires that a building be strengthened or removed. The ordinance applies to all buildings having bearing walls of unreinforced masonry that were constructed or under construction before 1933, or for which a building permit was issued prior to 1933, the effective date of the city's first seismic building code. The ordinance does not apply to detached one- or two-story single-family dwellings and detached apartment houses containing less than five dwelling units and used solely for residential purposes.

Affected buildings are classified according to type of function and occupancy as essential, high-risk, medium-risk, and low-risk buildings. See figure 6, section 91.6803. The strengthening standards and time schedules for notification and compliance vary with the risk category. A structural analysis of each individual building is also required in order to determine the remedial measures necessary to meet the appropriate standards. The city provides a specific time schedule.

An alternative compliance schedule, intended to lessen the financial and social impacts of the ordinance, gives a building owner the option of performing a portion of the remedial work within one year of notification in exchange for a longer time in which to reach full compliance. The work to be performed within a year involves the anchoring of unreinforced masonry walls to the roof and to each floor of the building with bolts and washers. According to the Los Angeles City Planning Department (1979, p. 5), this procedure yields an immediate and substantial improvement in safety for perhaps one-fifth the cost of full compliance.

Using the experience of the City of Los Angeles, the California Legislature (1986) requires all cities and counties in seismic zone 4 to identify hazardous unreinforced masonry buildings, establish a mitigation program, and notify the building owners. Local building departments are authorized to establish fees to recover the costs of identification. The mitigation program may include:

> the adoption by ordinance of a hazardous buildings program, measures to strengthen buildings, measures to change the use to acceptable occupancy levels or to demolish the building, tax incentives available for seismic rehabilitation, low-cost seismic rehabilitation loans ..., application of structural standards necessary to

provide for life safety above current code requirements, and other incentives to repair the buildings which are available from federal, state, and local programs.

Compliance with an adopted hazardous buildings ordinance or mitigation program is the responsibility of building owners. Nothing in the law makes any local government responsible for paying the cost of strengthening a privately-owned structure, reducing the occupancy, demolishing a structure, preparing engineering or architectural analysis, conducting investigations, or other costs associated with compliance of locally adopted mitigation programs.

A guidebook addressing unreinforced masonry buildings has been developed by the California Seismic Safety Commission (1987). The guidebook contains a series of steps for both identifying potentially hazardous buildings and developing and implementing a hazard-mitigation program including a model ordinance that provides for strengthening or removal of unsafe buildings. Other discussions include costs to local government, costs to building owners, incentives, and sources of information.

Some of the advantages of such ordinances are that deaths and injuries will be substantially reduced; economically-obsolete buildings will eventually be removed; land will be reused more efficiently; and repair or demolition will provide work for the construction industry. Some of the disadvantages of such ordinances are that some low-income housing will be lost; tenants probably will have to be relocated; and businesses will be interrupted.

ESTIMATING CASUALTIES, DAMAGE, AND INTERRUPTIONS

Several techniques to assist state and local governments in preparing for, responding to, and recovering from earthquake emergencies and disasters are available. One of the techniques is commonly called "loss estimates." A National Research Council (1989) panel defines an earthquake loss estimate as "a forecast of the effects of a hypothetical earthquake. Depending on its purpose, a loss study may include estimates of deaths and injuries; property losses; loss of function in industries, lifelines, and emergency facilities; homelessness; and economic impacts." These loss estimates are also effective techniques to create public awareness of hazards and support for the preparedness measures, response, and recovery operations. Four examples of loss estimates follow.

The Federal Emergency Management Agency (FEMA) (1981) estimated dead, hospitalized, injured but not hospitalized, loss to buildings, and loss to building contents for four postulated earthquakes in California (fig. 7). In addition, damage to or impact on selected facilities or needs were discussed. These included temporary housing, key communication facilities, military command circuits, all transportation modes, businesses, and industries. The FEMA and the California Office of Emergency Services then conducted an analysis of readiness for each of the areas and discussed Federal, State, and local responses and response planning.

The second example of loss estimates was prepared by Davis and others (1982). They created a planning scenario for a postulated earthquake in the Los Angeles region. A scenario is usually thought of as a synopsis or outline of a stage play or a cinema film; thus, a scenario for an earthquake can be considered a synopsis or outline of a large seismic event and its severe impacts on an urban region. Their scenario is used to assess the effects of a future earthquake on principal lifelines for emergency planning purposes. An analysis of readiness can then be used to provide planning insights, recommend further work, and serve as a basis for making or improving emergency preparedness, response, recovery, and reconstruction plans.

Davis and others (1982) include individual scenarios which show damage to lifelines such as highways, airports, railroads, marine facilities, communication lines, water-supply and waste-disposal facilities, and electrical power, natural gas, and petroleum lines. The scenarios for lifelines are based on evaluation of earthquake-engineering literature, comments by numerous engineers and officials of public agencies, and judgments by the authors. Their assessment of the earthquake effects was made to evaluate the resulting performance of lifeline segments throughout the region. The communications map, for example, assesses telephone-systems performance following the postulated earthquake (fig. 8). Other maps (those for water-supply and waste-disposal facilities, for example) show the location of and estimates of damage to specific facilities. Most of the planning maps for the scenario contain notations that are explained in the text. For example, one notation reads, "Water deliveries through the MWD Upper Feeder will be temporarily interrupted by pipe rupture where this major transmission line crosses the Santa Ana River." Most of the lifelines will sustain significant damage that could require a major emergency-response effort. Each scenario map is accompanied by a discussion of the general patterns of earthquake effects, for example:

> Interstate 5 from the San Joaquin Valley and Interstate 15 through Cajon Pass will be closed, leaving U.S. 101 along the coast as the only major viable route open from the north. Highway connections with San Diego will remain open.

> Not all of the (telephone) systems in the greater Los Angeles region are set up to process emergency calls automatically on previously established priority bases. Thus, overloading of equipment still in service could be very significant.

Similar scenarios of this type have been prepared for other earthquakes, for example, on the Hayward fault in the San Francisco Bay region by Steinbrugge and others (1987).

The third example of loss estimates was prepared by the U.S. Geological Survey (1975). It postulated an earthquake for two locations in the Puget Sound, Washington, area and concluded that under the worst conditions of exposure, as many as 2,200 deaths, 8,700 injuries, and 23,500 homeless was possible. In addition, anticipated damage patterns for five counties in the Puget Sound area were estimated for both earthquakes. A degree of impairment was assigned for selected critical facilities, equipment, or supplies (fig. 9). A detailed presentation of each of the impairments is included; for example:

- Damage to general hospitals having capacities of 50 or more beds.
- Deaths to physicians and nurses at nonhospital locations.
- Stock losses at retail drugstores and pharmacies.
- Damage to railroad bridges and tunnels.
- Probability of fatalities based upon siting of schools in areas of high damage intensities.

It should be noted that loss estimates, damage scenarios, and degrees of impairment are for planning purposes only, and some may consider them overly pessimistic. However, in emergency planning, it is important to consider severe levels of casualties and socioeconomic disruption to be better able to prepare, respond, and recover.

CLOSING COMMENTS

Prerequisites to the selection and implementation of an appropriate earthquake hazard-reduction technique from list 1 are:

- Conducting scientific and engineering studies of the physical processes of earthquake phenomena--source, location, size, likelihood of occurrence, triggering mechanism, path, ground response, structure response, and equipment response.
- Translating the results of such studies into reports and onto maps at an appropriate scale so that the nature and extent of the hazards and their effects are understood by nontechnical users.
- Transferring this translated information to those who will or are required to use it, and then assisting and encouraging them in its use.

SCIENTIFIC AND ENGINEERING STUDIES

Numerous geologic, geophysical, seismologic, and engineering studies are necessary to assess potential earthquake hazards. To give the nontechnical reader an overview, some of the studies are shown in the Proceedings of the 3rd Annual Workshop on "Earthquake hazards in the Puget Sound, Portland Area" (Hays, 1989, list 1, p. 193, 194).

It is not prudent for planners to develop land-use regulations, engineers to design structures, and lenders and public works directors to adopt policies reducing earthquake hazards without adequate and reliable scientific and engineering assessments. Many of these studies were envisioned and are described in the "Regional Earthquake Hazards Assessments" draft work plan for the Pacific Northwest. This plan is reproduced in a workshop proceedings by Hays (1988, p. 12-33).

TRANSLATION FOR NONTECHNICAL USERS

The specific objectives of translating scientific and engineering information for nontechnical users are to: make them aware that a hazard exists which may affect them or their interests; provide them with information that they can easily present to their superiors, clients, or constituents; and provide them with materials that can be directly used in a reduction technique.

My experience with reducing potential natural hazards indicates that natural-hazard information successfully used by nontechnical users has the following three elements in one form or another:

- Likelihood of the occurrence of an event that will cause casualties, damage, or disruption.
- Location and extent of the effects of the event on the ground.
- Estimated severity of the effects on the ground, structure, or equipment.

These elements are needed because engineers, planners, and decisionmakers usually will not be concerned with a potential hazard if its likelihood is rare, its location is unknown, or its severity is slight; neither will lenders, politicians, or citizens.

TRANSFER TO NONTECHNICAL USERS

The objective of transferring hazard information to nontechnical users is to assist in and encourage its use to reduce losses from future earthquakes. Translated hazard information is a prerequisite for transfer to nontechnical users. A comprehensive example of both the translation and transfer of geologic information for use by county planners and decision-makers is reported by Brabb (1987).

Various terms are used to convey "transfer" of information to users, namely, disseminate, communicate, circulate, promulgate, or distribute. Often these terms are interpreted conservatively, for example, merely issuing a press release on hazards or distributing research information to potential users. This level of activity usually fails to result in effective hazard reduction techniques and may even fail to make users aware of the hazard. Therefore, I suggest that we use "transfer" to mean the delivery of a translated product in a usable format at a scale appropriate to its use by a specific person or group "interested" in, or responsible for, hazard reduction. To delivery of a product, assistance and encouragement in its use for hazard reduction must be provided.

EVALUATION AND REVISION

The effectiveness of each hazard reduction technique varies with the time, place, and persons involved. Therefore, it is prudent to include a continuing systematic evaluation as part of any comprehensive earthquake-hazard reduction program. An inventory of uses made of the information, reports of interviews with the users, and an analysis of the results and responses will also result in identifying new users, innovative uses, as well as any problems concerning the scientific and engineering studies, their translation, transfer, and use. The evaluation will be helpful, even necessary, to those involved in producing, translating, transferring, and using the research information as well as to those funding and managing the program.

Performing the studies and then translating and transferring the research information is expensive and difficult because of the limited number of scientists and geotechnicians--national, state, local, corporate, and consulting--particularly when aligned with the needs of communities throughout the United States. The adoption and enforcement of an appropriate hazard reduction technique is time-consuming, and requires many skills--planning, engineering, legal, and political--as well as strong and consistent public support.

Scarce financial and staff resources must be committed and persistent and difficult actions must be taken to enact laws, adopt policies, or administer reduction programs over long periods of time. To discover later that the specific hazard reduction technique selected is ineffective, unenforced, or its cost is greatly disproportionate to its benefits is not only disheartening but may subject those involved to criticism and withdrawal of financial support!

CONCLUSION

The examples of earthquake-hazard reduction techniques presented in this chapter include: preparing redevelopment plans, creating regulatory zones, securing nonstructural building components, informing the public, strengthening unreinforced masonry buildings, and estimating casualties, damage, and interruptions.

The effect of these techniques is to provide greater public safety, health, and welfare for individuals and their communities. The decision to adopt each technique was influenced by many factors--the nature of the earthquake hazard, public concern, strong community interest, state enabling legislation, the availability of scientific and engineering information, and the ability of geologists, engineers, planners, and lawyers to incorporate the information into a hazard reduction technique.

Some of the geologic and seismologic information needed for land use and general planning in the Pacific Northwest region is available, but generally not at the level of detail and scale needed for engineering and decisionmaking. Even greater detail at larger scales ranging from 1:1,200 to 1:12,000 (1 in = 100 to 1,000 ft) is needed for other purposes, including development planning, site investigation, ordinance administration, project review, and permit issuance.

Earthquake-hazard research is continuing, the information base is improving, the methods for evaluating hazards are being developed, and new reduction techniques may be tested. Planners, engineers, and decisionmakers (both public and private) need to recognize these facts and use the latest information, methods, and techniques. However, they cannot be expected to have the training or experience necessary to understand and use untranslated scientific and engineering information. Therefore, if nontechnical users are to benefit from this information, it must be translated for and transferred to them before effective hazard-reduction techniques can be adopted.

ACKNOWLEDGEMENTS

Earl Brabb and Albert Rogers, U.S. Geological Survey, and Jeanne Perkins, Association of Bay Area Governments, provided many valuable suggestions and critical comments that have improved this chapter. Special thanks are owed Alice Olsen for processing the words.

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FIGURE CAPTIONS

FIGURE 1.--Part of the Santa Rosa City urban renewal project area modified from Mader and others (1980, fig. 7, p. C-8). Dot pattern indicates Phase I--original project area; medium screen indicates Phase II--area added following 1969 earthquakes; and dark screen indicates Phase III--survey area of additional land required for regional shopping center.

FIGURE 2.--Hypothetical surface-fault rupture regulatory zone from Brown and Kockelman (1983, fig. 30, p. 8) showing different ways that the ground may break. It illustrates the complexities of faulting, the necessity for the 400 m wide (1,320 ft) investigation zone required by the Alquist-Priolo Special Studies Zones Act, and the location of 15 m (50 ft) building setbacks required by the California Mining and Geology Board.

FIGURE 3.--Hypothetical property from Kockelman and Brabb (1979, fig. 6, p. 82) showing regulatory zones in an area of seismic and other geologic constraints. Dwelling units in the flood, surface-fault-rupture, and slope-instability zones are limited to one per 16 hectares (40 acres) by the San Mateo County Board of Supervisors (1973).

FIGURE 4.--This map is attached to the Redwood City Council (1977) building code, which requires special seismic design and construction standards for all new development on bay mud. Bay mud is indicated by shading; its southwesterly boundary by a dashed line. The unshaded areas lie outside the city's jurisdiction.

FIGURE 5.--Excerpt from Reitherman (1983, p. 39) showing how to reduce risk from earthquake damage for one type of nonstructural building component.

FIGURE 6.--Part of the Los Angeles City Council (1981) earthquake-hazard reduction ordinance requiring owners of buildings having unreinforced masonry bearing walls constructed before 1933 to obtain a structural analysis. If the building does not meet the minimum standards, the owner is required to strengthen or remove it according to a specific time schedule.

FIGURE 7.--Estimated consequences of a catastrophic earthquake occurring on each of four faults for three different times modified from the Federal Emergency Management Agency (1981, table 3, p. 23).

FIGURE 8.--Planning scenario impact of an earthquake on the telephone systems for part of the Los Angeles metropolitan region. Compilation by Davis and others (1982) shows the percentage of telephone-system effectiveness in four zones designated A, B, C, and D up to 3 days after the postulated earthquake. For example, in zone D near San Bernardino, only about 25 percent of the telephone system would be effective 3 days after the earthquake.

FIGURE 9.--Anticipated damage, impairment, and casualties from two postulated earthquakes in King County from a study on earthquake losses by the U.S. Geological Survey (1975, table 2, p. 5). Black squares indicate location of Seattle, Washington.

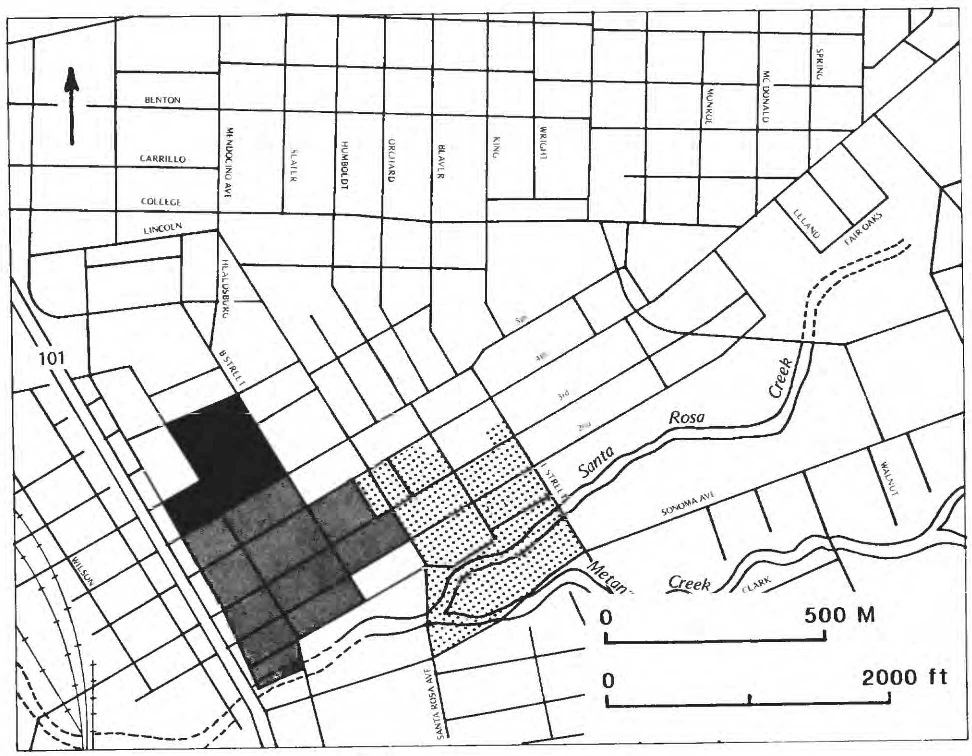

BENTON
CARRILLO
COLLEGE
LINCOLN
MENDOCINO AVE
HUMBOLDT
ORCHARD
KING
WRIGHT
MONROE
MC DONALD
SPRING
LELAND
FAIR OAKS
HEALDSBURG
B STREET
101
WILSON
3rd
E STREET
Santa
Rosa
Creek
SONOMA AVE
WALNUT
Creek
CLARK
SANTA ROSA AVE
0
500 M
0
2000 ft

Fig. 1

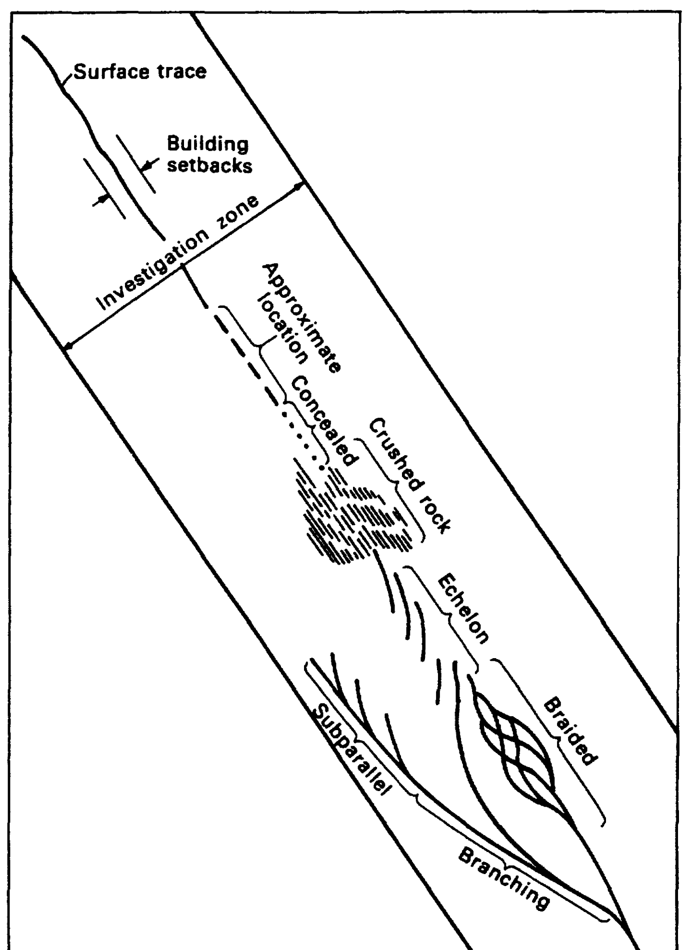
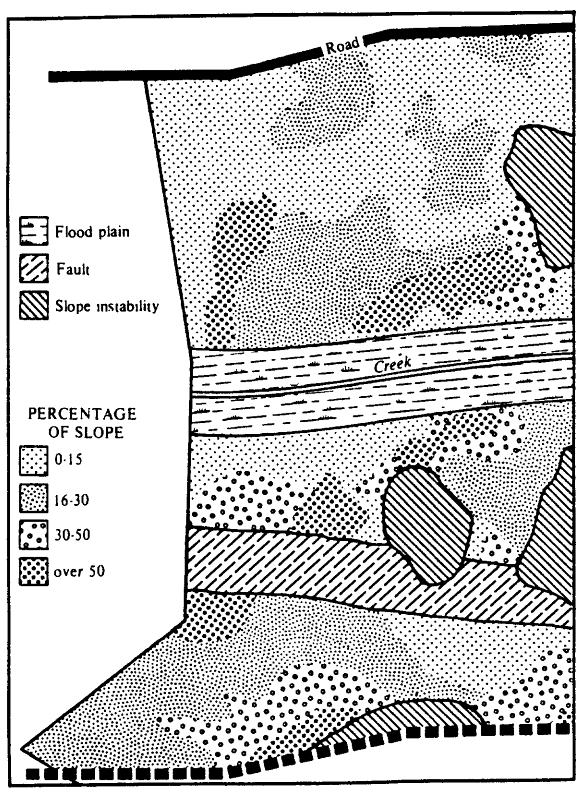

Surface trace
Building setbacks
Investigation zone
Approximate location
Concealed
Crushed rock
Echelon
Braided
Subparallel
Branching

Fig. 2



Road
Flood plain
Fault
Slope instability
Creek
PERCENTAGE
OF SLOPE
0-15
16-30
30-50
over 50

Fig. 3

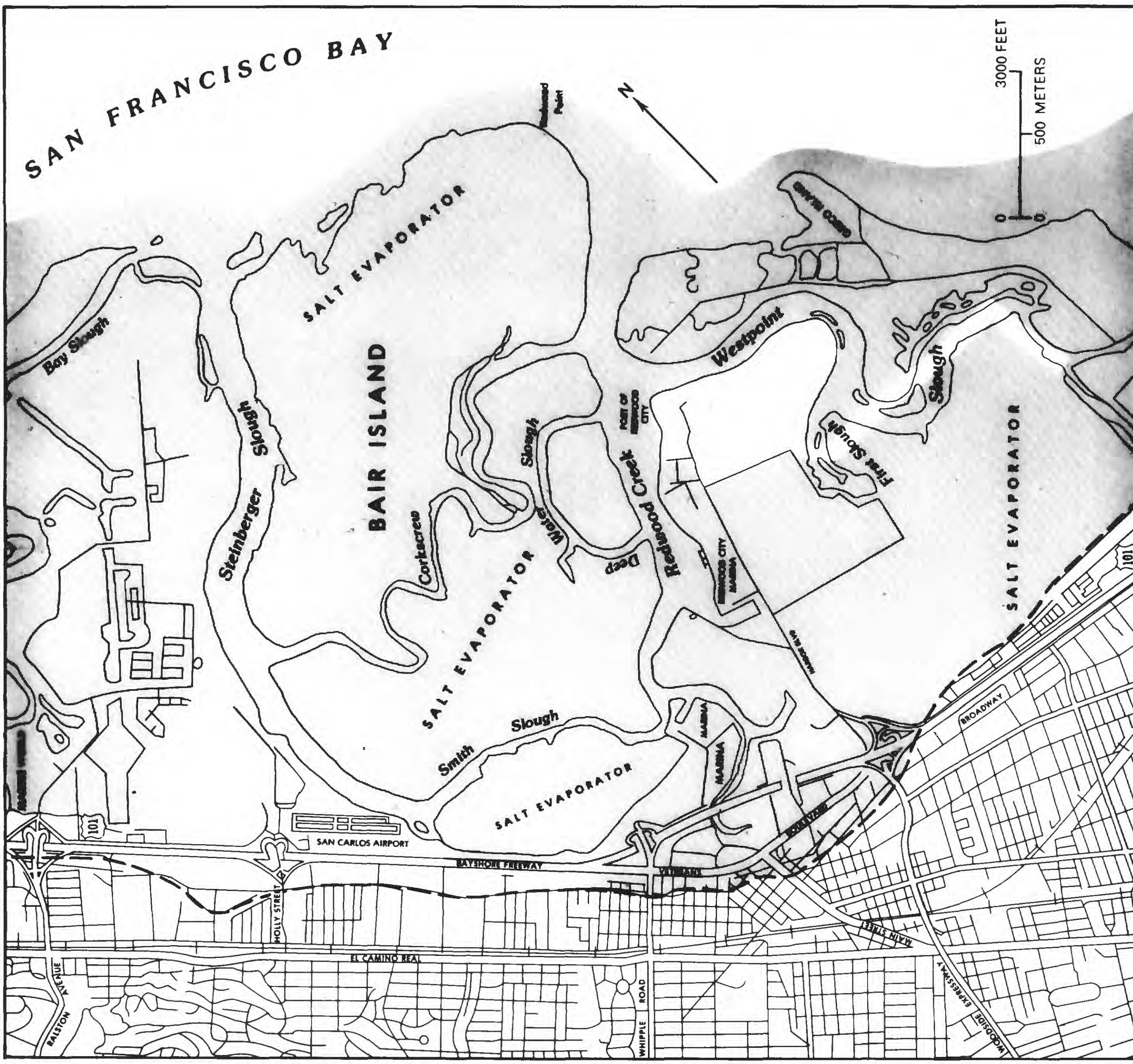
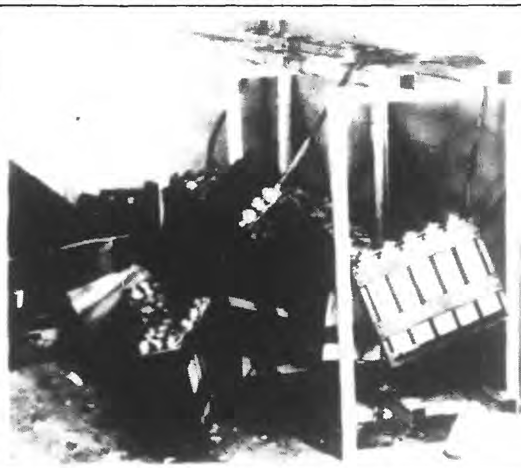

SAN FRANCISCO BAY
3000 FEET
500 METERS
0
N
SALT EVAPORATOR
BAIR ISLAND
Bay Slough
Steinberger Slough
Corkscrew
Smith Slough
Westpoint
Redwood Creek
First Slough
SALT EVAPORATOR
SALT EVAPORATOR
SALT EVAPORATOR
SAN CARLOS AIRPORT
BAYSHORE FREEWAY
HOLLY STREET
EL CAMINO REAL
RALSTON AVENUE
WHIPPLE ROAD
BROADWAY
MAIN STREET
WOODSIDE EXPRESSWAY
101

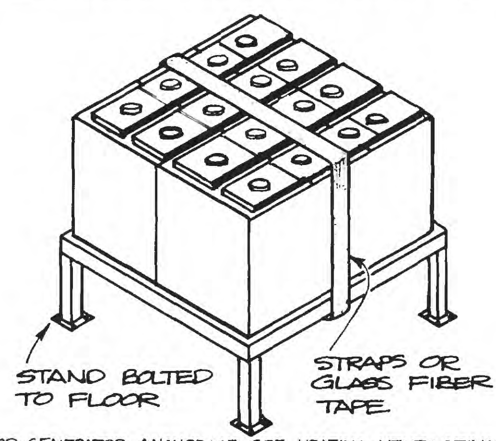
Fig. 4

EMERGENCY POWER GENERATORS

DAMAGE EXAMPLE	PROTECTIVE COUNTERMEASURE



earthquake: 1971 San Fernando
credit: John F. Meehan



APPROXIMATE COST: $10 per rack for strapping
$50 for bolting

EXISTING VULNERABILITY

SHAKING INTENSITY	EFFECTS	LIFE SAFETY HAZARD	$	POST-EARTHQUAKE OUTAGE
LIGHT	slight chance of piping connection break	low	0–5%	mod
MODERATE	slight shifting of equipment; batteries slide	low	5–20%	high
SEVERE	lurching of generator off supports; batteries fall	mod	20–50%	high

UPGRADED VULNERABILITY

SHAKING INTENSITY	EFFECTS	LIFE SAFETY HAZARD	$	POST-EARTHQUAKE OUTAGE
LIGHT	no damage	low	0%	low
MODERATE	no damage	low	0%	low
SEVERE	damage to rest of electrical system more likely than generator damage	low	0–5%	low

✚ LIFE SAFETY HAZARD $ % OF REPLACEMENT VALUE DAMAGED [chart symbol] POST–EARTHQUAKE OUTAGE

Fig. 5

Ordinance No. 154,807

An ordinance adding Division 68 of Article 1 of Chapter IX of the Los Angeles Municipal Code relative to earthquake hazard reduction in existing buildings.

Section 1. Article 1 of Chapter IX of the Los Angeles Municipal Code is hereby amended to add a Division 68 to read:

DIVISION 68 — EARTHQUAKE HAZARD REDUCTION IN EXISTING BUILDINGS

SEC. 91.6801. PURPOSE:

The purpose of this Division is to promote public safety and welfare by reducing the risk of death or injury that may result from the effects of earthquakes on unreinforced masonry bearing wall buildings constructed before 1934. Such buildings have been widely recognized for their sustaining of life hazardous damage as a result of partial or complete collapse during past moderate to strong earthquakes.

The provisions of this Division are minimum standards for structural seismic resistance established primarily to reduce the risk of life loss or injury and will not necessarily prevent loss of life or injury or prevent earthquake damage to an existing building which complies with these standards. This Division shall not require existing electrical, plumbing, mechanical or fire safety systems to be altered unless they constitute a hazard to life or property.

This Division provides systematic procedures and standards for identification and classification of unreinforced masonry bearing wall buildings based on their present use. Priorities, time periods and standards are also established under which these buildings are required to be structurally analyzed and anchored. Where the analysis determines deficiencies, this Division requires the building to be strengthened or demolished.

Portions of the State Historical Building Code (SHBC) established under Part 8, Title 24 of the California Administrative Code are included in this Division.

SEC. 91.6802. SCOPE:

The provisions of this Division shall apply to all builings constructed or under construction prior to October 6, 1933, or for which a building permit was issued prior to October 6, 1933, which on the effective date of this ordinance have unreinforced masonry bearing walls as defined herein.

EXCEPTION: This Division shall not apply to detached one or two story-family dwellings and detached apartment houses containing less than five dwelling units and used solely for residential purposes.

SEC. 91.6803. DEFINITIONS:

For purposes of this Division, the applicable definitions in Sections 91.2301 and 91.2305 of this Code and the following shall apply:

Essential Building: Any building housing a hospital or other medical facility having surgery or emergency treatment areas; fire or police stations; municipal government disaster operation and communication centers.

High Risk Building: Any building, not classified an essential building, having an occupant load as determined by Section 91.3301(d) of this Code of 100 occupants or more.

EXCEPTION: A high risk building shall not include the following:

1. Any building having exterior walls braced with masonry crosswalls or wood frame crosswalls spaced less than 40 feet apart in each story.

2. Any building used for its intended purpose, as determined by the Department, for less than 20 hours per week.

Historical Building: Any building designated as an historical building by an appropriate Federal, State or City jurisdiction.

Low Risk Building: Any building, not classified an essential building, having an occupant load as determined by Section 91.3301(d) of less than 20 occupants.

Medium Risk Building: Any building, not classified as a high risk building or an essential building, having an occupant load as determined by Section 91.3301(d) of 20 occupants or more.

Unreinforced Masonry Bearing Wall: A masonry wall having all of the following characteristics:

1. Provides the vertical support for a floor or roof.
2. The total superimposed load is over 100 pounds per linear foot.
3. The area of reinforcing steel is less than 50 percent of that required by Section 91.2418(e) of this Code.

SEC. 91.6804. RATING CLASSIFICATIONS:

The rating classifications as exhibited in Table No. 68-A are hereby established and each building within the scope of this Division shall be placed in one such rating classification by the Department. The total occupant load of the entire building as determined by Section 91.3301(d) shall be used to determine the rating classification.

EXCEPTION: For the purpose of this Division, portions of buildings constructed to act independently when resisting seismic forces may be placed in separate rating classifications.

TABLE NO. 68-A
RATING CLASSIFICATIONS

Type of Building	Classification
Essential Building	I
High Risk Building	II
Medium Risk Building	III
Low Risk Building	IV

SEC. 91.6805. GENERAL REQUIREMENTS:

The owner of each building within the scope of this Division shall cause a structural analysis to be made of the building by a civil or structural engineer or arthitect licensed by the State of California; and, if the building does not meet the minimum earthquake standards specified in this Division, the owner shall cause it to be structurally altered to conform to such standards; or cause the building to be demolished.

The owner of a building within the scope of this Division shall comply with the requirements set forth above by submitting to the Department for review within the stated time limits:

a. Within 270 days after the service of the order, a structural analysis. Such analysis which is subject to approval by the Department, shall demonstrate that the building meets the minimum requirements of this Division; or

b. Within 270 days after the service of the order, the structural analysis and plans for the proposed structural alterations of the building necessary to comply to the minimum requirements of this Division; or

c. Within 120 days after service of the order, plans for the installation of wall anchors in accordance with the requirements specified in Section 91.6808(c); or

d. Within 270 days after the service of the order, plans for the demolition of the building.

After plans are submitted and approved by the Department, the owner shall obtain a building permit, commence and complete the required construction or demolition within the time limits set forth in No. Table 68-B. These time limits shall begin to run from the date the order is served in accordance with Section 91.6806(a) and (b).

TABLE NO. 68-B
TIME LIMITS FOR COMPLIANCE

Required Action By Owner	Obtain Building Permit Within	Commence Construction Within	Complete Construction Within
Complete Structural Alterations or Building Demolition	1 year	180 days*	3 years
Wall Anchor Installation	180 days	270 days	1 year

*Measured from date of building permit issuance.

Owners electing to comply with Item c of this Section are also required to comply with Items b or d of this Section provided, however, that the 270-day period provided for in such Items b and d and the time limits for obtaining a building permit, commencing construction and completing construction for complete structural alterations or building demolition set forth in Table No. 68-B shall be extended in accordance with Table No. 68-C. Each such extended time limit, except the time limit for commencing construction shall begin to run from the date the order is served in accordance with Section 91.6806 (b). The time limit for commencing construction shall commence to run from the date the building permit is issued.

TABLE NO. 68-C
EXTENSIONS OF TIME AND SERVICE PRIORITIES

Rating Classification	Occupant Load	Extension of Time if Wall Anchors are Installed	Minimum Time Periods for Service of Order
I (Highest Priority)	Any	1 year	0
II	100 or more	3 years	90 days
III	100 or more	5 years	1 year
	More than 50, but less than 100	6 years	2 years
	More than 19, but less than 51	6 years	3 years
IV (Lowest Priority)	Less than 20	7 years	4 years

SEC. 91.6806. ADMINISTRATION:

(a) Service of Order. The Department shall issue an order, as provided in Section 91.6806(b), to the owner of each building within the scope of this Division in accordance with the minimum time periods for service of such orders set forth in Table No. 68-C. The minimum time period for the service of such orders shall be measured from the effective date of this Division. The Department shall upon receipt of a written request from the owner, order a building to comply with this Division prior to the normal service date for such building set forth in this Section.

(b) Contents of Order. The order shall be written and shall be served either personally or by certified or registered mail upon the owner as shown on the last equalized assessment, and upon the person, if any, in apparent charge or control of the building. The order shall specify that the building has been determined by the Department to be within the scope of this Division and, therefore, is required to meet the minimum seismic standards of this Division. The order shall specify the rating classification of the building and shall be accompanied by a copy of Section 91.6805 which sets forth the owner's alternatives and time limits for compliance.

(c) Appeal From Order. The owner or person in charge or control of the building may appeal the Department's initial determination that the building is within the scope of this Division to the Board of Building and Safety Commissioners. Such appeal shall be filed with the Board within 60 days from the service date of the order described in Section 91.6806(b). Any such appeal shall be decided by the Board no later than 60 days after the date that the appeal is filed. Such appeal shall be made in writing upon appropriate forms provided therefor, by the Department and the grounds thereof shall be stated clearly and concisely. Each appeal shall be accompanied by a filing fee as set forth in Table 4-A of Section 98.0403 of the Los Angeles Municipal Code.

Appeals or requests for slight modifications from any other determinations, orders or actions by the Department pursuant to this Division, shall be made in accordance with the procedures established in Section 98.0403.

(d) Recordation. At the time that the Department serves the aforementioned order, the Superintendent of Building shall file with the Office of the County Recorder a certificate stating that the subject building is within the scope of Division 68 — Earthquake Hazard Reduction in Existing Buildings — of the Los Angeles Municipal Code. The certificate shall also state that the owner thereof has been ordered to structurally analyze the building and to structurally alter or demolish it where compliance with Division 68 is not exhibited.

If the building is either demolished, found not to be within the scope of this Division, or is structurally capable of resisting minimum seismic forces required by this Division as a result of structural alterations or an analysis, the Superintendent of Building shall file with the Office of the County Recorder a certificate terminating the status of the subject building as being classified within the scope of Division 68 — Earthquake Hazard Reduction in Existing Buildings — of the Los Angeles Municipal Code.

(e) Enforcement. If the owner or other person in charge or control of the subject building fails to comply with any order issued by the Department pursuant to this Division within any of the time limits set forth in Section 91.6805, the Superintendent of Building shall order that the entire building be vacated and that the building remain vacated until such order has been complied with. If compliance with such order has not been accomplished within 90 days after the date the building has been ordered vacated or such additional time as may have been granted by the Board and the Superintendent may order its demolition in accordance with the provisions of Section 91.0103(o) of this Code.

SEC. 91.6807. HISTORICAL BUILDINGS:

(a) General. The standards and procedures established by this Division shall apply in all respects to an historical building except that as a means to preserve original architectural elements and facilitate restoration, an historical building may, in addition, comply with the special provisions set forth in this Section.

(b) Unburned Clay Masonry or Abode. Existing or re-erected walls of abode construction shall conform to the following:

1. Unreinforced abode masonry wall shall not exceed a height or length to thickness ratio of 5, for exterior bearing walls and must be provided with a reinforced bond beam at the top, interconnecting all walls. Minimum beam depth shall be 6 inches and a minimum width

Fig. 6

Fault	Time	Dead	Hospitalized[2]
Northern San Andreas (fault near San Francisco)	2:30 a.m.	3,000	12,000
	2:00 p.m.	10,000	37,000
	4:30 p.m.	11,000	44,000
Hayward (fault near Oakland)	2:30 a.m.	3,000	13,000
	2:00 p.m.	8,000	30,000
	4:30 p.m.	7,000	27,000
Southern San Andreas (fault near Los Angeles)	2:30 a.m.	3,000	12,000
	2:00 p.m.	12,000	50,000
	4:30 p.m.	14,000	55,000
Newport-Inglewood (fault in Los Angeles)	2:30 a.m.	4,000	18,000
	2:00 p.m.	21,000	83,000
	4:30 p.m.	23,000	91,000

[1] Uncertain by a possible factor of two to three.

[2] Injuries not requiring hospitalization are estimated to be from 15 to 30 times the number of deaths.

Fig. 7

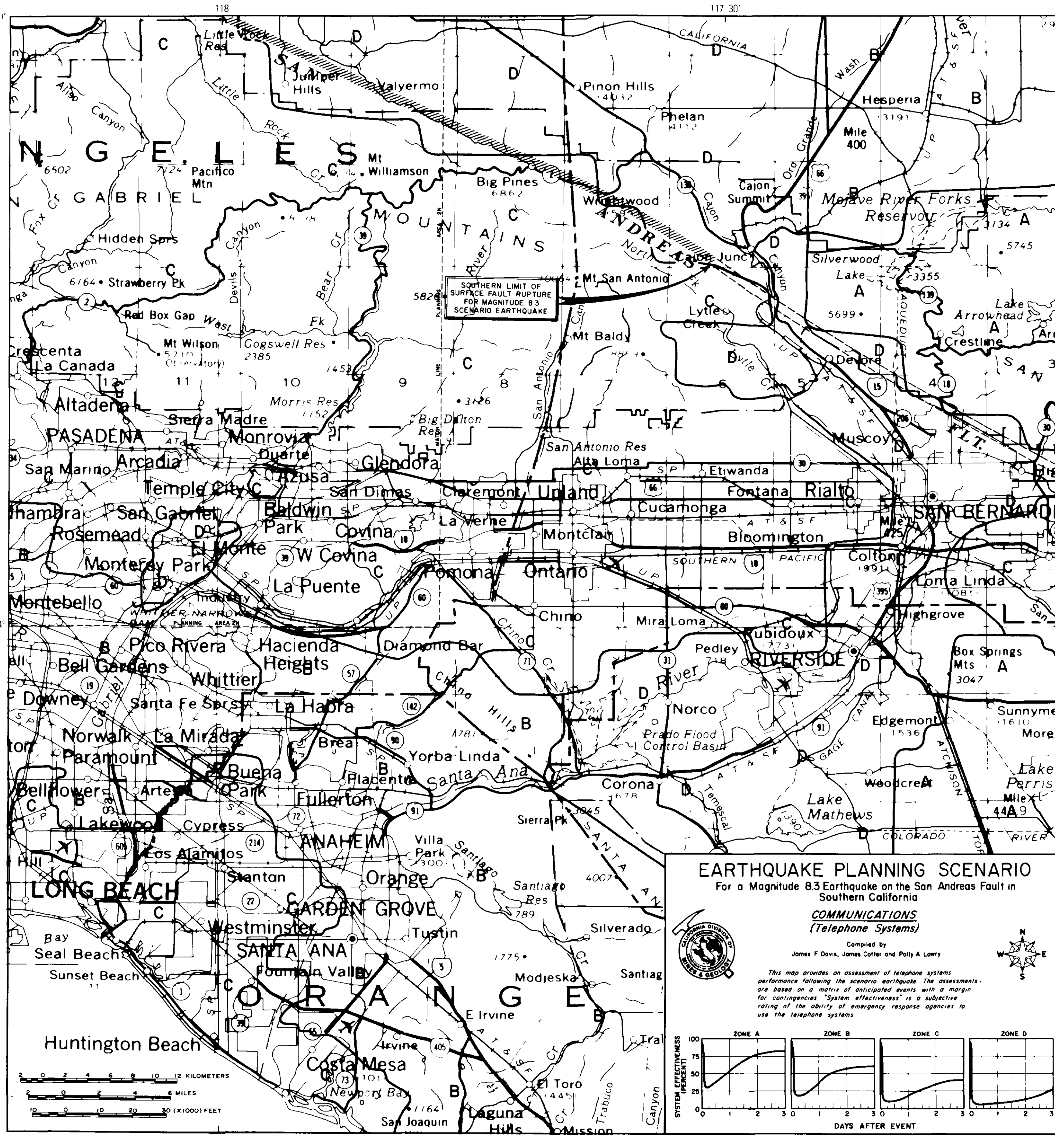
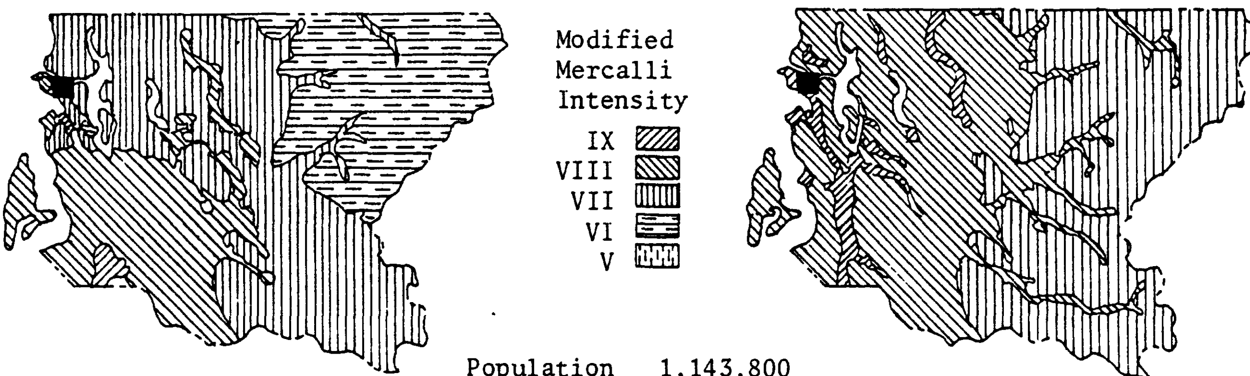

EARTHQUAKE PLANNING SCENARIO
For a Magnitude 8.3 Earthquake on the San Andreas Fault in Southern California
COMMUNICATIONS
(Telephone Systems)
Compiled by
James F Davis, James Cotter and Polly A Lowry
CALIFORNIA DIVISION OF MINES & GEOLOGY
This map provides an assessment of telephone systems performance following the scenario earthquake. The assessments are based on a matrix of anticipated events with a margin for contingencies "System effectiveness" is a subjective rating of the ability of emergency response agencies to use the telephone systems
ZONE A
ZONE B
ZONE C
ZONE D
SYSTEM EFFECTIVENESS (PERCENT)
100
75
50
25
0
0
1
2
3
DAYS AFTER EVENT
N
E
S
W
SOUTHERN LIMIT OF SURFACE FAULT RUPTURE FOR MAGNITUDE 8.3 SCENARIO EARTHQUAKE
KILOMETERS
MILES
(X1000) FEET
118
117 30'
SAN GABRIEL MOUNTAINS
ORANGE
Pasadena
Altadena
La Canada
Sierra Madre
Monrovia
Arcadia
San Marino
Duarte
Azusa
Glendora
Temple City
San Gabriel
Rosemead
El Monte
Monterey Park
Montebello
Baldwin Park
Covina
W Covina
La Puente
San Dimas
Claremont
La Verne
Pomona
Upland
Ontario
Montclair
Chino
Cucamonga
Alta Loma
Etiwanda
Fontana
Rialto
Bloomington
Colton
SAN BERNARDINO
Loma Linda
Highgrove
RIVERSIDE
Rubidoux
Pedley
Mira Loma
Norco
Corona
Prado Flood Control Basin
Edgemont
Woodcrest
Lake Mathews
Lake Perris
Box Springs Mts
Sunnymead
Pico Rivera
Bell Gardens
Whittier
Downey
Santa Fe Sprs
La Habra
Norwalk
La Mirada
Paramount
Bellflower
Artesia
Buena Park
Lakewood
Cypress
Los Alamitos
LONG BEACH
Brea
Yorba Linda
Placentia
Fullerton
ANAHEIM
Orange
Villa Park
Stanton
GARDEN GROVE
Westminster
SANTA ANA
Tustin
Fountain Valley
Seal Beach
Sunset Beach
Huntington Beach
Costa Mesa
Newport Bay
Irvine
E Irvine
El Toro
Laguna Hills
San Joaquin
Mission
Silverado
Modjeska
Santiago Res
Sierra Pk
Hacienda Heights
Diamond Bar
Chino Hills
Santa Ana
Industry
Mt Wilson
Cogswell Res
Morris Res
Big Dalton Res
Red Box Gap
Strawberry Pk
Hidden Sprs
Pacifico Mtn
Mt Williamson
Big Pines
Wrightwood
Mt San Antonio
Mt Baldy
Lytle Creek
Devore
San Antonio Res
Little Rock Res
Juniper Hills
Valyermo
Pinon Hills
Phelan
Hesperia
Cajon Summit
Cajon Junc
Mojave River Forks Reservoir
Silverwood Lake
Lake Arrowhead
Crestline
Muscoy
SAN ANDREAS FLT.
CALIFORNIA

Fig. 8

Postulated earthquake "A"   Postulated earthquake "B"



Population 1,143,800
Area in mi^2 2,128

Vital needs	Degree of impairment					
	Earthquake "A"			Earthquake "B"		
	Minimal	Minor	Major	Minimal	Minor	Major
Communications----------		●				●
Fire--------------------		●				●
Police------------------		●				●
Electric power----------			●			●
Water-------------------		●				●
Access roadways---------			●			●
Medical:						
Manpower--------------			●			●
Hospitals-------------			●			●
Ambulances------------		●				●
Blood bank------------		●				●
Supplies--------------		●			●	
Food supplies-----------	●				●	
Schools (as shelters)---		●				●

	Estimated losses	
	Earthquake "A"	Earthquake "B"
Deaths--------------------	1,500	1,650
Serious injuries----------	6,000	6,600
Homeless------------------	7,130	18,630

Fig. 9