June 2, 2014 Project No.130-2916

Will Cipes
PHR LA Mart, LLC
3191 Casitas Avenue, Suite 130
Los Angeles, California 90039

RE: REVIEW OF FAULTING AND OTHER SEISMIC HAZARDS FOR DEVELOPMENT PROJECT, LOS ANGELES, CALIFORNIA

Dear Mr. Cipes:

Golder Associates Inc. ("**Golder**") has prepared this technical report (the "**Report**") to present its findings of a review of available information on potential active faulting and other seismic hazards for an approximately 10-acre property located at 1900 and 1933 South Broadway in Los Angeles, California (APN No.s: 5126-030-005, 5126-030-006, 5126-030-009, 5126-030-011, 5126-031-009, 5126-031-010) (collectively, the "**Property**").

1.0 PROJECT UNDERSTANDING

The Property is currently developed with the approximately 866,000 square foot, 12-story Reef building and a surface parking lot. The proposed project consists of improvements and additions to the existing Reef building and the construction of approximately 1,900 residential dwelling units, a 250 room hotel, and 100,000 square feet of commercial space (the "**Project**"). In addition, the Project will include a subterranean parking structure and an above grade parking structure. A preliminary site plan is included as Attachment A.

2.0 SCOPE OF WORK COMPLETED

Golder performed an office-based review of available information regarding fault activity and seismic hazards at the Property. Our review addressed the following:

- Assess the presence of known active faults or earthquake fault zones crossing the Property.
- Assess whether the Property is located in a mapped seismic hazard zone.
- Provide preliminary peak ground and spectral accelerations suitable for application of the 2013 California Building Code for the Property.

Golder reviewed the following documents in order to complete the tasks outlined above:

- "State of California Special Studies Zones Revised Official Map, Hollywood Quadrangle", prepared by the State of California Resources Agency, Department of Conservation, Division of Mines and Geology, dated July 1, 1986, attached hereto as Attachment B.
- "State of California Seismic Hazard Zones Official Map, Hollywood Quadrangle", prepared by the State of California Resources Agency, Department of Conservation, Division of Mines and Geology, dated March 25, 1999, attached hereto as Attachment C.
- "Seismic Hazard Zone Report for the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California (Seismic Hazard Zone Report 026)", prepared by the State of

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California Resources Agency, Department of Conservation, Division of Mines and Geology, dated 1998, attached hereto as Attachment D.

- "Fault Evaluation Report FER-173, Northern Newport-Inglewood Fault Zone, Los Angeles County, California", prepared by the State of California Resources Agency, Department of Conservation, Division of Mines and Geology, dated November 15, 1986, attached hereto as Attachment E.
- "Puente Hills Blind-Thrust System, Los Angeles, California", Bulletin of the Seismological Society of America, Vol. 92, No. 8, pp. 2946-2960, December 2002. (Shaw et al. 2002), attached hereto as Attachment F.
- "Safety Element of the Los Angeles City General Plan", prepared by the Department of City Planning, Los Angeles, California, Approved by the City Planning Commission August 8, 1996; adopted by the City Council November 26, 1996, attached hereto as Attachment G.

In addition to the documents above, Golder consulted the following websites:

- California Department of Conservation (http://www.conservation.ca.gov).
- United States Geological Survey (http://www.usgs.gov).
- The Zone Information and Map Access System for the City of Los Angeles (ZIMAS) (http://www.zimas.lacity.org).
- Southern California Earthquake Center (SCEC) (http://www.scec.org).

3.0 FINDINGS

3.1 Alquist-Priolo Earthquake Fault Zones

The Alquist-Priolo Earthquake Fault Zoning Act, enacted in 1972, requires the State of California Geologist to delineate boundaries around known active faults. The purpose of the Alquist-Priolo Earthquake Fault Zoning Act is to regulate development near active faults to mitigate the hazard of surface fault rupture. Under California law, an active fault is one that has evidence for surface rupture in the Holocene Epoch (approximately the last 11,000 years).

Since 1972, earthquake fault zone maps have been prepared by the State Geologist. Earthquake fault zones have been defined around most of the known active faults in California. Where mapped, the boundaries of these earthquake fault zones are generally approximately 500 feet on either side of the mapped active fault trace(s). If a proposed development is located within the boundaries of the earthquake fault zone drawn by the State Geologist, then an investigation must be undertaken to establish whether the trace of an active fault is located on the proposed development site. If an active fault is found at the site, then a structure for human occupancy cannot be constructed over the trace of the fault and must be set back from the fault trace (generally 50 feet) to avoid the fault rupture hazard.

The Property is not located within an Alquist-Priolo Earthquake Fault Zone.

3.2 Other Fault Zones

The Alquist-Priolo Earthquake Fault Zoning Act applies to the entire State of California, and fault investigations are required for sites within these fault zones as described above. Local jurisdictions may also establish their own special studies fault zones where the State has not yet mapped potentially active faults. The current version of the Safety Element of the Los Angeles City General Plan contains a section on faults and establishes Fault Rupture Study Areas. The Property is not located within a Fault Rupture Study Area.

The City of Los Angeles Department of Building and Safety (LADBS) requires investigations for ground surface rupture due to earthquake faulting for properties located within Alquist-Priolo Earthquake Fault Zones. Projects located outside of an Earthquake Fault Zone are exempt from this requirement per the City of Los Angeles. However, the exemption does not preclude the Grading Division of LADBS from requiring an investigation outside of the established zones, when a property is located in the proximity of a known fault. The property is not located in the proximity of a known fault.

The Property is located within the Los Angeles Segment of the Puente Hills Blind Thrust Fault System, as indicated by ZIMAS and Shaw et al. (2002).

As noted by SCEC, "…the Puente Hills thrust fault is "blind" because it never breaks through at the surface, instead producing folds in the rocks above it, which may sometimes be expressed as chain of low hills, raised up by successive earthquakes along the fault below." These "low hills" or warping of the ground surface would be most evident where the projection of the fault would daylight on the ground surface (the fault trace).

The Property is not located within the fault traces mapped by Shaw et al (2002) for the Puente Hills Blind Thrust Fault System. Based on Shaw et al. (2002), the Property is located approximately 1.5 miles to the north of the Puente Hills Fault trace and approximately 1.5 miles south of the upper Elysian Park fault. However, given its location within the Puente Hills Blind Thrust Fault System, and its location approximately 4 km above the east-dipping fault plane, the Property could be subjected to very strong ground shaking during the Project's design life, as discussed in Section 3.4 below.

3.3 Other Seismic Hazard Zones

The State of California Seismic Hazards Mapping Act, updated in 2007, requires the State Geologist to compile maps identifying seismic hazard zones. These seismic hazards include liquefaction, slope instability, tsunamis, and seiches. Under the Act, cities and counties must require that a geotechnical report for proposed developments address the seismic hazards if a site is located within a mapped Seismic Hazard Zone.

The Property is not located within a mapped Seismic Hazard Zone.

3.4 Ground Shaking

The Property is located in the seismically active region of Southern California. As with all development in Southern California, the Property is expected to be subjected to earthquake-related hazards during its design life. One potential seismic hazard is strong earthquake ground shaking. In general, the strongest shaking can be expected closest to major high slip rate and seismically active faults because they generate frequent and large earthquakes (e.g. the San Andreas fault). Faults with lower slip rates typically have less frequent and smaller magnitude earthquakes.

As noted in Section 3.2, above, the Property is located near the Los Angeles segment of the Puente Hills Blind Thrust Fault System and approximately 4 km above the Puente Hills Fault plane. According to Shaw et al. (2002), the Puente Hills fault has broken at least four times in the previous 11,000 years, and has generated large earthquakes in excess of magnitude 7.

Preliminary building code seismic design parameters are provided in Table 1, below. These parameters are provided as initial values to indicate the general magnitude of ground motions expected at the Property. They are based on the assumption that the Property is underlain by Site Class D soils and that the proposed structures on Property will be Risk Category I, II, or III. We can provide revised, design-level seismic parameters after completing a geotechnical investigation at the Property.

Table 1. Preliminary 2013 California Building Code (CBC) Seismic Design Parameters

2013 CBC Seismic Design Parameter	Value
Site Class	**D**
5%-damped, 0.2-sec spectral acceleration (S_S)	**2.21**
5%-damped, 1-sec spectral acceleration (S_1)	**0.78**
Site Class D, 5%-damped , maximum considered earthquake geometric mean (MCEG) peak ground acceleration	
Site Coefficient, F_a	**1.0**
Site Coefficient, F_v	**1.5**
Site Coefficient, F_{pga}	**1.0**

4.0 CONCLUSIONS

Golder concludes the following based on the information reviewed:

- The Property is not located within a State of California Alquist-Priolo Earthquake Fault Zone.
- The Property is not located within a Fault Rupture Study Area as identified in the 1996 Safety Element of the Los Angeles City General Plan.
- Surface fault rupture has not been reported and is not expected at the Property.
- The Property is not located within a State of California Seismic Hazard Zone.
- Design earthquake ground motions at the Property are expected to be high because of its location in the Los Angeles basin and location above the Puente Hills fault plane.

5.0 LIMITATIONS

This Report has been prepared for the exclusive use of PHR LA Mart, LLC. The findings, conclusions, and recommendations presented in this Report were prepared in a manner consistent with the level of care and skill ordinarily exercised by other members of the geotechnical engineering profession currently practicing under similar conditions subject to the time limits and financial, physical, and other constraints applicable to the scope of work. No warranty, express or implied, is made.

This Report is not written as a report of geotechnical design recommendations or as a specification document and should not be used as such.

7.0 CLOSING

Golder appreciates the opportunity to be of service on this Project. If you have any questions, please contact any of the undersigned at (714) 508-4400.

GOLDER ASSOCIATES INC.

Jaime Bueno, PE
Senior Engineer

Alan Hull, PhD, CEG
Principal

cc: Edgar Khalatian, Mayer Brown LLP

jlb/ah

ATTACHMENT A

Reference: Preliminary Site Plan provided by Mayer Brown LLP, undated

CLIENT/PROJECT	**PHR LA Mart, LLC** **LA Mart Project**	Golder Associates	TITLE	**Preliminary Site Plan**

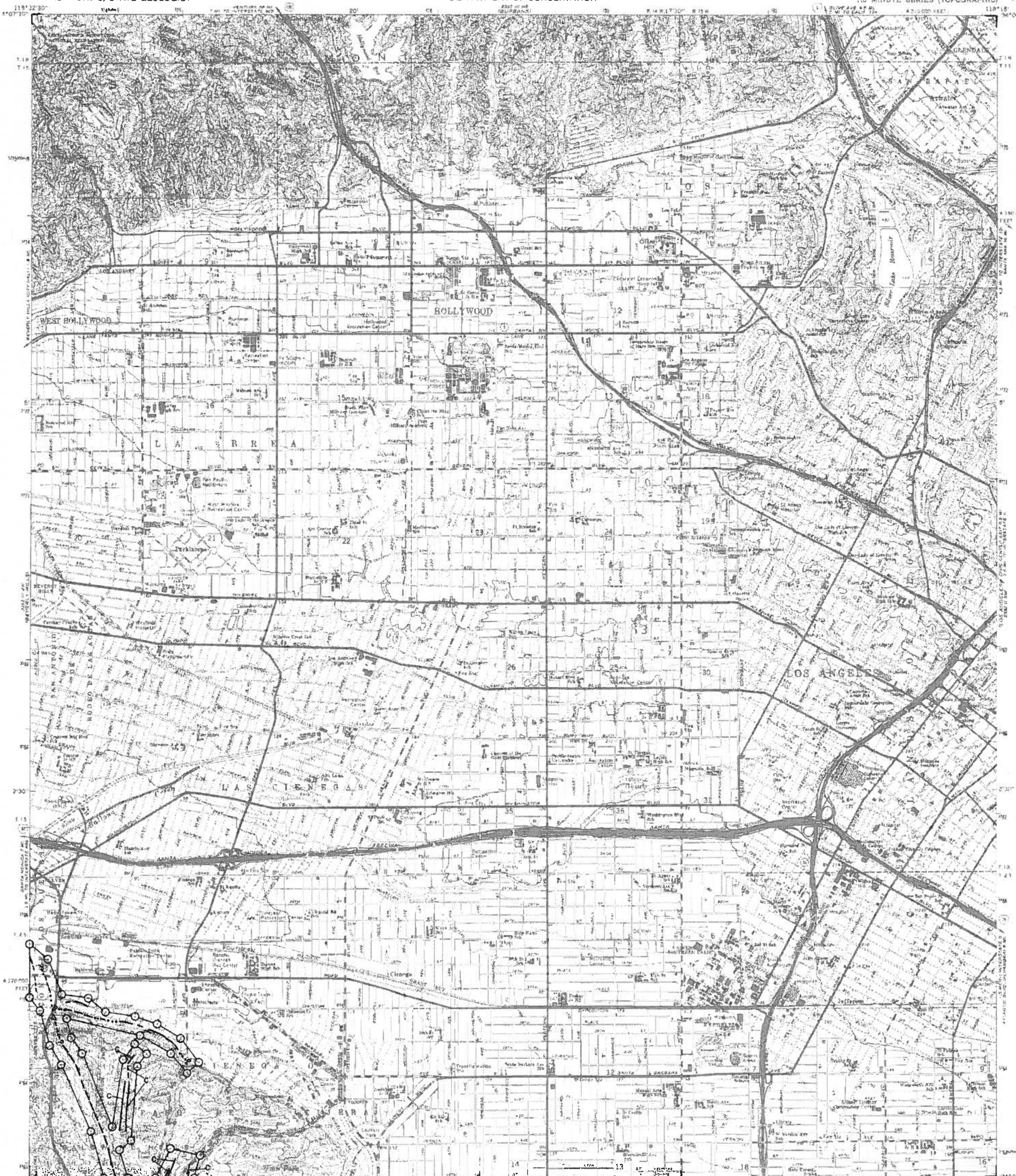
DRAWN	CHECKED	REVIEWED	DATE	SCALE	FILE NO.	JOB NO.	DWG NO.	SUBTITLE	REV. NO.	**Attachment A**
JLB	JLB	AH	06/02/2014	Not to Scale	N/A	130-2916	N/A	N/A	N/A	

ATTACHMENT B

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION

HOLLYWOOD QUADRANGLE
CALIFORNIA—LOS ANGELES CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



TOPOGRAPHIC BASE MAP BY U.S. GEOLOGICAL SURVEY 1966
PHOTOREVISED 1981

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET
DASHED LINES REPRESENT 10 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

MAP EXPLANATION

Potentially Active Faults

Faults considered to have been active during Holocene time and to have a relatively high potential for surface rupture; solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed; query (?) indicates additional uncertainty. Evidence of historic offset indicated by year of earthquake-associated event or C for displacement caused by creep or possible creep.

Special Studies Zone Boundaries

These are delineated as straight-line segments that connect encircled turning points so as to define special studies zone segments.

Seaward projection of zone boundary

STATE OF CALIFORNIA
SPECIAL STUDIES ZONES

Delineated in compliance with Chapter 7.5, Division 2 of the California Public Resources Code
(Alquist-Priolo Special Studies Zones Act)

HOLLYWOOD QUADRANGLE

REVISED OFFICIAL MAP

Effective: July 1, 1986

James F. Davis State Geologist

REFERENCES USED TO COMPILE FAULT DATA

Hollywood Quadrangle

Bryant, W.A., 1985, Northern Newport-Inglewood fault zone, Los Angeles County: California Division of Mines and Geology Fault Evaluation Report FER-171 (unpublished).

Castle, R.O., and Yerkes, R.F., 1976, Recent surface movements in the Baldwin Hills, Los Angeles County, California: U.S. Geological Survey Professional Paper 882, 125 p., 4 plates, scale 1:12,000.

For additional information on faults in this map area, the rationale used for zoning, and additional references consulted, refer to unpublished Fault Evaluation Reports on file at the DMG office in Pleasant Hill.

IMPORTANT - PLEASE NOTE

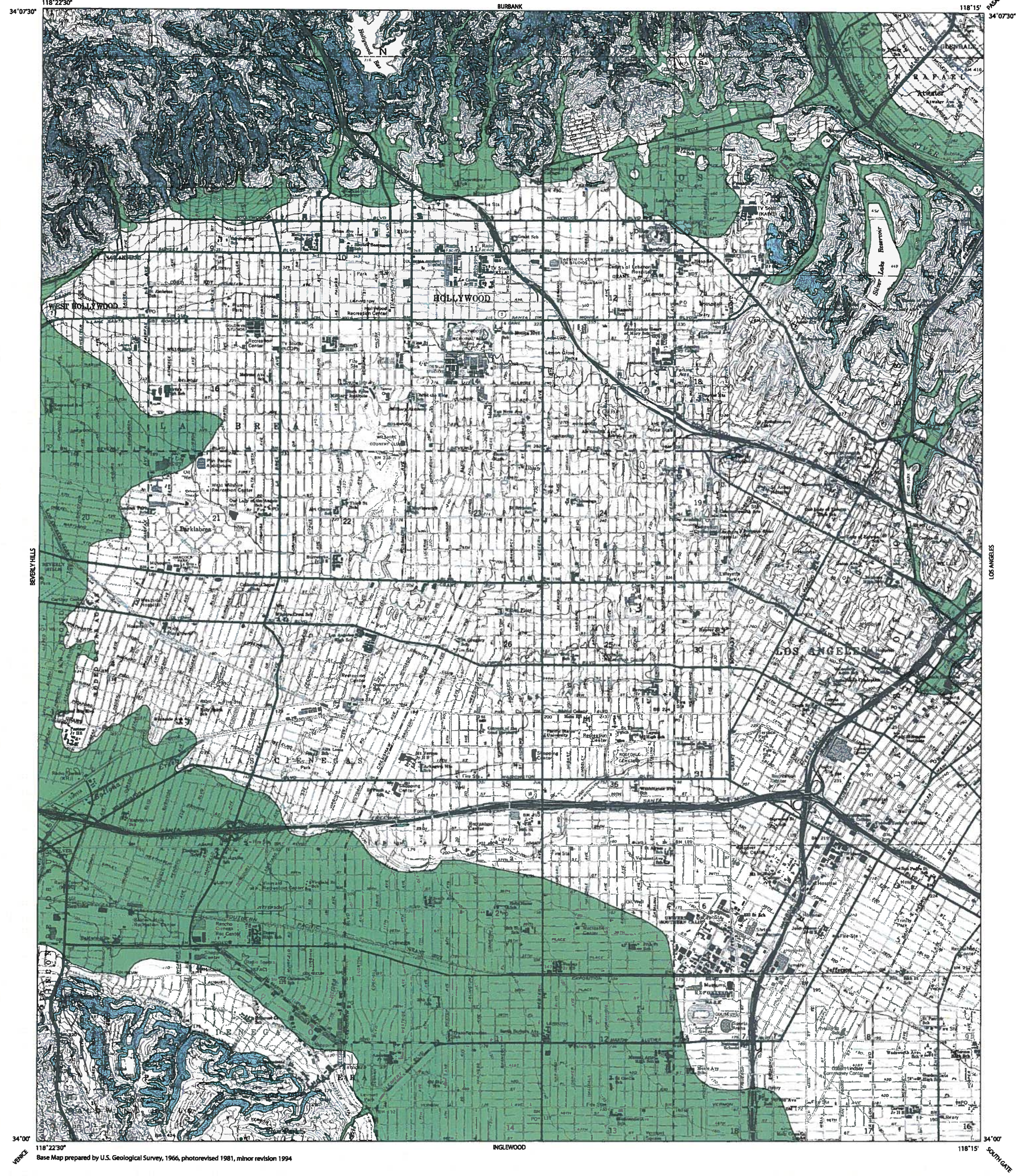
1) *This map may not show all faults that have the potential for surface fault rupture, either within the special studies zones or outside their boundaries.*
2) Faults shown are the basis for establishing the boundaries of the special studies zones.
3) The identification and location of these faults are based on the best available data. However, the quality of data used is varied. Traces have been drawn as accurately as possible at this map scale.
4) Fault information on this map is not sufficent to serve as a substitute for the geologic site investigations (special studies) required under Chapter 7.5 of Division 2 of the California Public Resources Code.

ATTACHMENT C

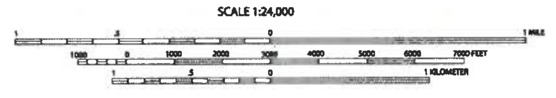
DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, STATE GEOLOGIST

STATE OF CALIFORNIA-GRAY DAVIS, GOVERNOR
THE RESOURCES AGENCY-MARY D. NICHOLS, SECRETARY
DEPARTMENT OF CONSERVATION-STEVE ARTHUR, CHIEF DEPUTY DIRECTOR

SEISMIC HAZARD ZONES MAP
Hollywood Quadrangle



Base Map prepared by U.S. Geological Survey, 1966, photorevised 1981, minor revision 1994



PURPOSE OF MAP

This map will assist cities and counties in fulfiling their responsibilities for protecting the public safety from the effects of earthquake-triggered ground failure as required by the Seismic Hazards Mapping Act (Public Resources Code Sections 2690-2699.6).

For information regarding the scope and recommended methods to be used in conducting the required site investigations, see DMG Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California.

For a general description of the Seismic Hazards Mapping Program, the Seismic Hazards Mapping Act and regulations, and related information, please refer to the draft User's Guide (see http://www.consrv.ca.gov/dmg/shezp/userguid/).

Production of this map was funded by the Federal Emergency Management Agency's Hazard Mitigation Program and the Department of Conservation in cooperation with the Governor's Office of Emergency Services.

IMPORTANT - PLEASE NOTE

1) This map may not show all areas that have the potential for liquefaction, landsliding, strong earthquake ground shaking or other earthquake and geologic hazards. Also, a single earthquake capable of causing liquefaction or triggering landslide failure will not uniformly affect the entire area zoned.

2) Liquefaction zones may also contain areas susceptible to the effects of earthquake-induced landslides. This situation typically exists at or near the toe of existing landslides, downslope from rockfall or debris flow source areas, or adjacent to steep stream banks.

3) This map does not show Alquist-Priolo earthquake fault zones, if any, that may exist in this area. Please refer to the latest official map of earthquake fault zones for disclosures and other actions that are required by the Alquist-Priolo Earthquake Fault Zoning Act. For more information on this subject and an index to available maps, see DMG Special Publication 42.

4) Landslide zones on this map were determined, in part, by adapting methods first developed by the U.S. Geological Survey (USGS). A new generation of landslide hazard maps being prepared by the USGS (Jibson and Harp, in preparation) uses an experimental approach designed to explore new methods to assess earthquake-induced landslide hazards. Although aspects of this new methodology may be incorporated in future seismic hazard zone maps, the experimental USGS maps should not be used as substitutes for these official earthquake-induced landslide zone maps.

5) U.S. Geological Survey base map standards provide that 90 percent of cultural features be located within 40 feet (horizontal accuracy) at the scale of this map. The identification and location of liquefaction and earthquake-induced landslide zones are based on available data. However, the quality of data used is varied. The zone boundaries depicted have been drawn as accurately as possible at this scale.

6) Information on this map is not sufficient to serve as a substitute for the geologic and geotechnical site investigations required under Chapters 7.5 and 7.8 of Division 2 of the Public Resources Code.

7) DISCLAIMER: The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data from which these maps were derived. Neither the State nor the Department shall be liable under any circumstances for any direct, indirect, special, incidental or consequential damages with respect to any claim by any user or any third party on account of or arising from the use of this map.

STATE OF CALIFORNIA

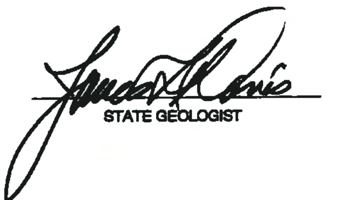
SEISMIC HAZARD ZONES

Delineated in compliance with
Chapter 7.8, Division 2 of the California Public Resources Code
(Seismic Hazards Mapping Act)

HOLLYWOOD QUADRANGLE

OFFICIAL MAP

Released: March 25, 1999



STATE GEOLOGIST

MAP EXPLANATION

Zones of Required Investigation:

Liquefaction
Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

Earthquake-Induced Landslides
Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

DATA AND METHODOLOGY USED TO DEVELOP
THIS MAP ARE PRESENTED IN THE FOLLOWING:

Seismic Hazard Evaluation of the Hollywood 7.5 minute quadrangle, Los Angeles County, California: California Division of Mines and Geology, Open-File Report 98-17.

For additional information on seismic hazards in this map area, the rationale used for zoning, and additional references consulted, refer to DMG's World Wide Web site (http://www.consrv.ca.gov/dmg/).

ATTACHMENT D

SEISMIC HAZARD ZONE REPORT 026

SEISMIC HAZARD ZONE REPORT FOR THE HOLLYWOOD 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

STATE OF CALIFORNIA
GRAY DAVIS
GOVERNOR

THE RESOURCES AGENCY
MARY D. NICHOLS
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
DARRYL YOUNG
DIRECTOR

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

SEISMIC HAZARD ZONE REPORT 026

SEISMIC HAZARD ZONE REPORT FOR THE HOLLYWOOD 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

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List of Revisions – Hollywood SHZR 026	
2001	Text updated
6/10/05	BPS address corrected, web links updated, Figure 3.5 added
1/13/06	Southern California and Bay Area Regional offices address update

CONTENTS

ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Hollywood 7.5-minute Quadrangle, Los Angeles County, California. The map displays the boundaries of Zones of Required Investigation for liquefaction and earthquake-induced landslides over an area of approximately 62 square miles at a scale of 1 inch = 2,000 feet.

The Hollywood Quadrangle includes portions of the cities of Beverly Hills, West Hollywood, Culver City, Glendale, Los Angeles (including the communities of Hollywood, Los Feliz, Silverlake, Echo Park, Atwater Village, Park La Brea, Hancock Park, Country Club Park, Crenshaw, and Westlake), and the unincorporated Los Angeles County communities of View Park and Baldwin Hills lie within the quadrangle. The southern slope of the Santa Monica Mountains is in the northern part of the quadrangle. South of the mountains is the La Brea plain and younger alluvial fans that form part of the Hollywood piedmont slope. The Los Angeles Narrows separates the Elysian Park Hills, in the northeastern quarter of the quadrangle, from the Repetto Hills. The Baldwin Hills lie in the southwest corner of the map south of Ballona Gap. Access is via the Santa Monica Freeway (I-10), the Hollywood Freeway (U.S. Highway 101), the Golden State Freeway (I-5), and the Harbor Freeway (State Highway 110). Residential and commercial development is densely concentrated in the area south of the Santa Monica Mountains. Hillside residential development began in the 1920's and continues today. The City of Los Angeles' Griffith Park covers the eastern end of the Santa Monica Mountains. Other land uses include state and national parklands and recreation areas, oil fields, golf courses, and reservoirs.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years.

In the Hollywood Quadrangle the liquefaction zone is located in the bottoms of canyons and along the southern base of the Santa Monica Mountains, in the Los Angeles River floodplain, and in a broad area where ground water is shallow along the western and southern parts of the quadrangle. The combination of dissected hills and weak rocks has locally produced abundant landslides. However, the lack of hillside terrain in much of the quadrangle means that only 5 percent of the quadrangle lies in an earthquake-induced landslide hazard zone.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet page: http://www.conservation.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
945 Bryant Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Hollywood 7.5-minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By
Elise Mattison and Ralph C. Loyd

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Holywood 7.5-minute Quadrangle. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996).

Additional information on seismic hazards zone mapping in California is on DMG's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Hollywood Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on DMG probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Hollywood Quadrangle consist mainly of alluviated valleys, floodplains, and canyons. DMG's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The heavily urbanized Hollywood Quadrangle encompasses about 60 square miles in central Los Angeles County and includes all or parts of the cities of Beverly Hills, Culver City, Glendale, Los Angeles (including the communities of Hollywood, Los Feliz, Silverlake, Echo Park, Atwater Village, Park La Brea, Hancock Park, Country Club Park, Crenshaw, and Westlake), and West Hollywood, as well as some unincorporated areas of Los Angeles County. The center of the quadrangle is about 4 miles west of the Los Angeles Civic Center.

The southern slopes of the eastern Santa Monica Mountains, which include peaks more than 1,600 feet in elevation, fill the northern margin of the quadrangle. The Los Angeles River flows from northwest to southeast across the northeast corner, hugging the northeastern edge of the Elysian Hills, which rise about 400 feet above the surrounding plain. The La Brea Plain dominates the center of the quadrangle, and the deeply dissected Baldwin Hills rise in the southwest corner. Between the latter two, the Ballona Gap, along Ballona Creek, marks the course of an ancestral west-flowing Los Angeles River. The largest reservoirs are the Hollywood Reservoir in the Santa Monica Mountains and the Silver Lake Reservoir in the Elysian Hills.

GEOLOGY

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. A Quaternary geologic map of the Hollywood Quadrangle (Yerkes, 1997) was obtained in digital form from the U.S. Geological Survey (USGS). Additional sources of geologic information used in this evaluation include Tinsley and Fumal (1985) and Dibblee (1991). DMG staff modified mapped contacts between alluvium and bedrock and remapped the Quaternary units in more detail. Stratigraphic nomenclature was revised to follow the format developed by the Southern California Areal Mapping Project (SCAMP) (Morton and Kennedy, 1989).

Plate 1.1, the revised geologic map used in this study, shows that most of the Hollywood Quadrangle is covered by Quaternary alluvial basin and fan deposits consisting mainly of sand, silt, and clay. Older Quaternary deposits (Qoa) are exposed over most of the elevated region of the La Brea Plain, and there are two generations of younger alluvial deposits (Qya1, Qya2) in the lower areas beyond the plain. Other Quaternary deposits in the quadrangle include modern streambed sediments (Qw) along the Los Angeles River, Holocene alluvial fan deposits exposed in the northeast corner of the quadrangle, and older alluvial fan sediments (Qof) deposited along the northern base of the Baldwin Hills. Section 2 of this report describes lower Quaternary, Tertiary, and pre-Tertiary rocks exposed in the Santa Monica Mountains, Elysian Hills, and the Baldwin Hills in the Hollywood Quadrangle.

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from reports on geotechnical and environmental projects. For this investigation, about 470 borehole logs were collected from the files of the California Department of Transportation (CalTrans); the California Regional Water Quality Control Board, Los Angeles Region; DMG Environmental Review and Hospital Review Projects, and private consultants. The USGS supplied copies of storm drain investigations logs collected from the Los Angeles County Department of Public Works.

Borehole log selection focused on, but was not limited to, drill sites in Quaternary sedimentary deposits. Data from the borehole logs were entered into a DMG geotechnical GIS database (Plate 1.2). Computer-constructed cross sections enabled staff to relate soil-engineering properties to various depositonal units, correlate soil types from one borehole to another, and extrapolate geotechnical data into outlying areas containing similar soils.

Standard Penetration Test (SPT) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows by a 140-pound drop weight required to drive a sampler of specific dimensions one foot into the soil. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), were converted to SPT-equivalent blow count values and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

On the surface, younger alluvium in the Hollywood Quadrangle is differentiated by geomorphic relationships and mapped as Qya1 or Qya2, but these units could not be distinguished in the subsurface. The young Quaternary alluvial deposits (Qya1, Qya2) exposed between the La Brea Plain and the Santa Monica Mountains (Hollywood area) consist mainly of clayey sand and silt that overlie older Quaternary deposits at depths of 10 to 15 feet. Most of these sediments likely accumulated as slope wash and debris flow deposits along the base the Santa Monica Mountains. In contrast, the young alluvial sediments in the southern part of the quadrangle contain an abundance of loose to moderately dense sand with lesser amounts of silt, clay, and peat. These sediments were deposited along and adjacent to the ancestral Los Angeles River, which once flowed through the area.

No borehole data were collected for the younger fan deposits (Qyf1) in the northeast corner of the quadrangle. However, boreholes in young fan deposits in the adjoining Los Angeles Quadrangle encountered alternating beds of silt and loose to moderately dense fine- to coarse-grained sand with some clay and abundant gravel.

Borehole samples from the Los Angeles River channel (Qw) range from very fine to coarse sand and very loose to very dense sand, silty sand, and gravel. The sequence of alternating layers of sediment, in places less than 20 feet thick, rests on dense shale.

GROUND-WATER CONDITIONS

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water table within alluviated areas.

DMG identified historically shallow water in the western and southwestern parts of the Hollywood Quadrangle. Shallow ground water was also found in the Los Angeles River floodplain in the extreme northeastern corner and in canyons that drain the highlands. In drainages, sediments on shallow and impermeable bedrock collect water and can remain saturated for long periods, especially during wet seasons.

Ground-water conditions were investigated in the Hollywood Quadrangle to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation was based on first-encountered water noted in geotechnical borehole logs acquired from technical publications, geotechnical boreholes, and water-well logs dating back to the early 1900s (Mendenhall, 1905). The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not utilized. As a check against any major discrepancies Plate 1.2 was compared to the published maps of Tinsley and others (1985), Leighton and Associates (1990), and Los Angeles City (1996).

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. This method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Pleistocene bedrock (Qi, Qsp)

Deformed early Pleistocene marine siltstone and sandstone of the Inglewood Formation and Pleistocene marine sand and gravel of the San Pedro Formation are exposed in the Baldwin Hills. These very old Quaternary units are not typically susceptible to liquefaction.

Pleistocene alluvial deposits (Qoa, Qof)

Old Quaternary sedimentary deposits are exposed over much of the center of the Hollywood Quadrangle and within, and adjacent to, the Baldwin Hills in the southeast corner. In general, older alluvium in the Hollywood Quadrangle consists of layers of fine to coarse clayey sand and sandy clay, with lesser amounts of silt. The only exposure of older fan material is on the lower slopes of the Baldwin Hills. The few borehole logs examined depict alternating layers of silty clay and clayey silt, with some sand and gravel. Liquefaction of Pleistocene sedimentary units is not likely in the Hollywood Quadrangle.

Holocene deposits (Qya1-2, Qyfl, Qw)

Where saturated within 40 feet of the ground surface (Plate 1.2), most young Quaternary units in the Hollywood Quadrangle are judged to be susceptible to liquefaction. However, younger Quaternary sediments exposed in the Hollywood area probably won't liquefy because they are dominated by clayey silts and sands and lie above historic high ground-water levels.

Artificial fill (af)

Artificial fill sites in the Hollywood Quadrangle include freeways, dams and slope grading. Since these fills are assumed to be properly engineered, the liquefaction susceptibility of the underlying material is the significant factor in seismic hazard zoning.

Map Unit	Age	Environment of Deposition	Primary Textures	General Consistency	Susceptible to Liquefaction?*
Qw	Historical	active stream channels	sand, gravel, silty sand	loose to dense	yes
Qyfl	latest Holocene	alluvial fans	sand, gravel, sandy silt	loose to moderately dense	yes
Qya2, Qya1	Holocene	floodplains, streams, alluvial fans	sand, silt, clay	loose to moderately dense	yes
Qof	late Pleistocene?	alluvial fans	clay, silt	moderately dense to dense	not likely
Qoa	late Pleistocene?	basins	sand, clay	dense to very dense	not likely
Qsp, Qi,	Pleistocene	shallow marine	sand, gravel, siltstone, sandstone	very dense	not likely

*when saturated

Table 1.1. General Geotechnical Characteristics and Liquefaction Susceptibility of Quaternary Deposits in the Hollywood Quadrangle.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Hollywood Quadrangle, PGAs of 0.45 g to 0.59 g, resulting from earthquakes ranging in magnitude from 6.4 to 6.9, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion section (3) of this report for further details.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, DMG's analysis uses the Idriss magnitude scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures. The DMG liquefaction analysis program calculates an FS for each geotechnical sample for which blow counts were collected. Typically, multiple samples are collected for each borehole. The lowest FS in each borehole is used for that location. FS values vary in reliability according to the quality of the geotechnical data used in their calculation. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 470 geotechnical borehole logs reviewed in this study (Plate 1.2), 273 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes
2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable
4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Hollywood Quadrangle is summarized below.

Areas of Past Liquefaction

Historical liquefaction has not been reported in the Hollywood Quadrangle, nor is there any known evidence of paleoseismic liquefaction. Therefore, no areas in the Hollywood Quadrangle are zoned for potential liquefaction based on historic liquefaction.

Artificial Fills

Non-engineered artificial fills have not been delineated or mapped in the Hollywood Quadrangle. Consequently, no such areas within the Hollywood Quadrangle are zoned for potential liquefaction based on their presence.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. Liquefaction analyses of geotechnical data recorded in logs of boreholes drilled in the Hollywood Quadrangle show that young, saturated sandy soils are potentially liquefiable. Accordingly, areas characterized as such are included in zones of required investigation.

Areas with Insufficient Existing Geotechnical Data

Younger alluvium deposited in canyon bottoms and incised channels generally lack adequate geotechnical borehole information. The soil characteristics and ground-water conditions in these cases are assumed to be similar to those in deposits where subsurface information is available. The canyon and incised stream channel deposits, therefore, are delineated as zones of required investigation for reasons presented in criterion 4a above.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By
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Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Hollywood 7.5-minute Quadrangle. This section, along with Section 1 (addressing liquefaction), and Section 3 (addressing earthquake shaking), form a report that is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet web page: http://www.conservation.ca.gov/CGS/index.htm.

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Hollywood Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area

- Seismological data in the form of DMG probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a DMG pilot study (McCrink and Real, 1996) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Hollywood Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Hollywood Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Hollywood Quadrangle covers approximately 62 square miles in southwestern Los Angeles County. Portions of the cities of Beverly Hills, West Hollywood, Culver City, Glendale, Los Angeles (including the communities of Hollywood, Los Feliz, Silverlake, Echo Park, Atwater Village, Park La Brea, Hancock Park, Country Club Park, Crenshaw, and Westlake), and the unincorporated Los Angeles County communities of View Park and Baldwin Hills lie within the quadrangle. The center of the quadrangle is about 4 miles west of the Los Angeles Civic Center.

The northernmost part of the quadrangle is dominated by hilly and mountainous terrain along the southern slope of the eastern Santa Monica Mountains. Numerous steep-sided, north-trending ridges extend from the crest to the coastal plain of the Los Angeles Basin. The La Brea plain, which lies along the southern flank of the Santa Monica Mountains, is an older, dissected alluvial surface that has been warped into several anticlinal structures. Younger alluvial fans, which form part of the Hollywood piedmont slope, have been deposited on the older alluvial plain by streams draining the Santa Monica Mountains. The northeast quarter of the quadrangle is occupied by the Elysian Park Hills, a group of deeply dissected hills with moderate relief. The Los Angeles Narrows, an erosional feature cut by the Los Angeles River, separates these hills from the Repetto Hills to the east beyond the quadrangle.

The Baldwin Hills, a prominent domal uplift along the Newport-Inglewood structural zone, lie in the southwest corner of the map area south of Ballona Gap. The northern slope of the Baldwin Hills has been warped, faulted, and deeply incised by erosion. The southern third of the quadrangle, east of Baldwin Hills, consists of a gently sloping alluvial surface formed by deposition from local drainages and the ancestral Los Angeles River.

Major freeways in the quadrangle include: the Santa Monica Freeway (I-10), which traverses the area from west to east, the Hollywood Freeway (U.S. Highway 101), which cuts diagonally through the Elysian Park Hills and Santa Monica Mountains in a northwest direction, the Golden State Freeway (I-5), which follows the Los Angeles River at the east edge of the Santa Monica Mountains and Elysian Park Hills, and the Harbor Freeway (State Highway 110), which passes through the southeast quarter of the map in a north-northeast direction.

Residential and commercial development is densely concentrated in the area south of the Santa Monica Mountains. Hillside residential development began in the 1920's and 1930's, grew rapidly after World War II, and continues today. The City of Los Angeles' Griffith Park, which contains the Griffith Park Observatory, the Greek Theater, and numerous hiking trails, occupies the eastern end of the Santa Monica Mountains. Other current land uses include: state and national parklands and recreation areas, oil fields, golf courses, and reservoirs, including the Hollywood Reservoir and Silver Lake Reservoir.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface. Within the Hollywood Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours that are based on 1964 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

To update the terrain data, areas that have recently undergone large-scale grading in the hilly portions of the Hollywood Quadrangle were identified. Only one area that has undergone large-scale grading since 1963 as part of residential development was identified on 1:40,000-scale aerial photography flown in 1994 and 1995 (NAPP, 1994). Terrain data for this area were produced by scanning and rectifying diapositives made from the photography. Using this stereo-rectified image, DMG manually digitized the terrain to produce accurate and up-to-date topography for the mass graded area. The corrected terrain data were digitally merged with the USGS DEM. Plate 2.1 shows the area where topography is updated to 1994 grading conditions.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

A recently compiled U.S. Geological Survey (USGS) geologic map was obtained in digital form (Yerkes, 1997) for the Hollywood Quadrangle. The contacts between bedrock and alluvium from the digital file were extensively modified to conform to the topographic contours of the USGS 7.5-minute quadrangle. Bedrock geology was also modified to reflect more recent mapping. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted. Landslide deposits were deleted from the map so that the distribution of bedrock formations and the landslide inventory would exist on separate layers for the hazard analysis.

The oldest geologic unit mapped in the Hollywood Quadrangle is the Cretaceous granodiorite and quartz diorite (Kgr), which is exposed in the northern part of the map area in the Santa Monica Mountains. Locally, at the surface, the granitic rocks are soft and crumbly due to weathering. Because of their fractured and deeply weathered nature, they are prone to landslides and debris flows on moderate to steep slopes. A small outcrop of the Wilson Quartz Diorite (gneissic, wqg) is exposed in the northeast corner of the quadrangle.

In the northwest corner of the quadrangle, Cretaceous granite is overlain unconformably by deep-marine clastic sedimentary rocks of the Cretaceous Tuna Canyon Formation (Kt), which consists of interbedded sandstone, siltstone, and pebble-cobble conglomerate. Overlying the Tuna Canyon Formation are the Paleocene and Eocene nonmarine clastic sedimentary rocks of the Simi Conglomerate and Las Virgenes Sandstone and marine fine-grained sandstones of the Santa Susana Formation (Colburn and Novak, 1989).

Because of the map scale, all of the Paleocene and Eocene rocks are included in the Santa Susana Formation (Tss; Coal Canyon Formation of Yerkes and Campbell, 1979).

Other Tertiary bedrock formations in the Santa Monica Mountains include the shallow-marine clastic sedimentary rocks and volcanics of the middle Miocene Topanga Group and deep-marine biogenic and clastic rocks of the upper Miocene Modelo Formation. The Topanga Group consists of massive sandstone with interbedded shale and siltstone (Tts), pebbly sandstone and conglomerate (Ttc), and basalt flows (Tb). The Modelo Formation is composed of interbedded shale, siltstone, and sandstone (Tm). These formations are prone to slope failure where bedding planes are inclined in the same direction as the slope.

The Elysian Park Hills are primarily composed of deep-marine clastic and biogenic rocks of the upper Miocene Puente Formation. These rocks consist of interbedded and interfingering siltstone and fine sandstone (Tpn1), siliceous shale and siltstone (Tpn2), diatomaceous shale and siltstone (Tpn3), and fine- to coarse-grained, thinly laminated to thick-bedded sandstone (Tpn4). The southern end of the Elysian Park Hills is composed of massive, soft, micaceous marine siltstone of the Pliocene Fernando Formation (Tf3).

The Baldwin Hills are primarily composed of marine sediments of Pleistocene age. Stratigraphic correlation of Plio-Pleistocene and Quaternary strata within the Los Angeles Basin is difficult because of rapid lateral facies changes resulting from fluctuations in the paleo-shoreline and the time-transgressive nature of the faunal assemblages (Quinn and others, 1997). Because of the current lack of well-defined Quaternary correlations and nomenclature, the formation designations used in this study for the Baldwin Hills area should be regarded as generalized and informal.

The oldest Quaternary unit mapped in the Hollywood Quadrangle is the lower Pleistocene Inglewood Formation (Qi; "A" formation of Castle, 1960), which is exposed on the northern slope of the Baldwin Hills. It is composed of thinly interbedded siltstone and fine sandstone deposited in a shallow marine environment. Unconformably overlying the Inglewood Formation, is the Pleistocene San Pedro Formation (Qsp; "B" formation of Castle, 1960), which consists of poorly consolidated, fine- to coarse-grained sand interbedded with thin beds and lenses of gravel deposited in a near-shore marine environment ("Qc" in Weber and others, 1982). Also included in this unit are fluvial sand and gravel with local beds of clayey silt ("Qb" in Weber and others, 1982). A reddish brown, well-cemented and resistant, locally pebbly or gravelly, silty sand caps some of the ridges in the southern edge of the map and is designated older alluvium (Qoa; "Qf" in Weber and others, 1982; "cap deposits" in Castle, 1960).

Quaternary sediments covering the remainder of the Hollywood Quadrangle include older and younger alluvial-fan deposits (Qof, Qoa, and Qya1) and floodplain and stream deposits in the basin and the canyons (Qya1 and Qya2). Landslides (Qls and Qls?) occur on steep slopes in the Santa Monica Mountains and on the northern slope of the Baldwin Hills. Modern man-made (artificial) fills (af) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Hollywood Quadrangle can be found in Section 1.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Hollywood Quadrangle was prepared (Irvine, unpublished) by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation: Curtis (1980), Fairchild (1927), NASA (1994), USDA (1952/54), and USGS (1994). Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Byer, 1987; CDWR, 1961; Dibblee, 1991; Harp and Jibson, 1995; Hoots, 1930; Lamar, 1970; L.A. Dept. of Public Works, 1963; Neuerburg, 1953; Poland and others, 1959; Weber and others, 1982; and Weber and others, 1979). Landslides were mapped and digitized at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the slope stability analysis. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed hand-drawn landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the rock units identified on the Hollywood Quadrangle geologic map were obtained from the City of Los Angeles, Department of Public Works and CDMG publications (see Appendix A). The locations of rock and soil samples taken for shear testing by consultants are shown on Plate 2.1. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information. For the Hollywood Quadrangle, shear test values used to calculate rock strength were borrowed from adjacent quadrangles. All shear tests for Tm were taken from the Burbank Quadrangle. Additional values for Qsp were obtained from the Venice Quadrangle. No shear tests were available for af, Kt, TK, Ttc, Tts, Tss, and all Quaternary units except for Qa, and these geologic units were added to existing groups on the basis of lithologic and stratigraphic similarities.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean and median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Adverse Bedding Conditions

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can slip along bedding surfaces due to a lack of lateral support.

To account for adverse bedding in our slope stability evaluation, we used geologic structural data in combination with digital terrain data to identify areas with potentially adverse bedding, using methods similar to those of Brabb (1983). The structural data, derived from the geologic map database, was used to categorize areas of common bedding dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude was less than or equal to the slope gradient category but greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area.

The formations, which contain interbedded sandstone and shale, were subdivided based on shear strength differences between coarse-grained (higher strength) and fine-grained (lower strength) lithologies. Shear strength values for the fine- and coarse-grained lithologies were then applied to areas of favorable and adverse bedding orientation, which were determined from structural and terrain data as discussed above. It was assumed that coarse-grained material (higher strength) dominates where bedding dips into a slope (favorable bedding) while fine-grained (lower strength) material dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength values to areas where potential adverse bedding conditions were identified. The favorable and adverse bedding shear strength parameters for the formations are included in Table 2.1.

Existing Landslides

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily "residual" strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used.

The results of the grouping of geologic materials in the Hollywood Quadrangle are in Tables 2.1 and 2.2.

HOLLYWOOD QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	**Number Tests**	**Mean/ Median Phi**	**Mean/ Median Group phi (deg)**	**Group Mean/ Median C (psf)**	**No Data: Similar Lithology**	**Phi Values Used in Stability Analysis**
GROUP 1	Kgr	28	40.5/40	40.5/40	483/440		40.5
GROUP 2	Tpn4(fbc) Tb Tm(fbc) Tt(fbc) Tpn1(fbc)	27 22 22 36 16	34.2/34 33.8/33.5 33.5/34.5 33.0/34.7 31.4/31	33.2/34	597/500	Kt Ttc(fbc) Tts(fbc) TK	33.2
GROUP 3	Qi Tt(abc) Tf3 Qa Qsp Tpn Tpn4(abc) Tpn1(abc)	35 17 3 6 30 5 5 30	29.9/29 29.8/31 29/28 28.8/29 28.2/30 27.8/29 27.4/26 26.8/26	28.5/29	366/300	af, Qao Qay1, Qay2 Qc?,Qoa Qof?,Qp, Qt Qw, Qyal Qya2, Qyfl Tss	28.5
GROUP 4	Tpn3 Tm(abc)	16 20	23/19 22/22	22.4/20.1	392/364		22.4
GROUP 5	Qls	-	-	-	-		14

abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength

Table 2.1. Summary of the Shear Strength Statistics for the Hollywood Quadrangle.

SHEAR STRENGTH GROUPS FOR THE HOLLYWOOD QUADRANGLE				
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
Kgr	Kt Tb Tm(fbc) Tpn1(fbc) Tpn4(fbc) Tt(fbc) Ttc(fbc) Tts(fbc) TK	af Qa Qay1,2 Qc? Qi Qoa Qof? Qp Qsp Qt Qw Qya1,2 Qyf1 Tf3 Tpn Tpn1(abc) Tpn4(abc) Tt(abc) Tss	Tm(abc) Tpn3	Qls

Table 2.2. Summary of the Shear Strength Groups for the Hollywood Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Hollywood Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.4 to 6.9
Modal Distance:	2.5 to 6.4 km
PGA:	0.43 to 0.59 g

The strong-motion record selected for the slope stability analysis in the Hollywood Quadrangle was the Channel 3 (N35°E horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge Earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a peak ground acceleration (PGA) of 0.59 g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Hollywood Quadrangle.

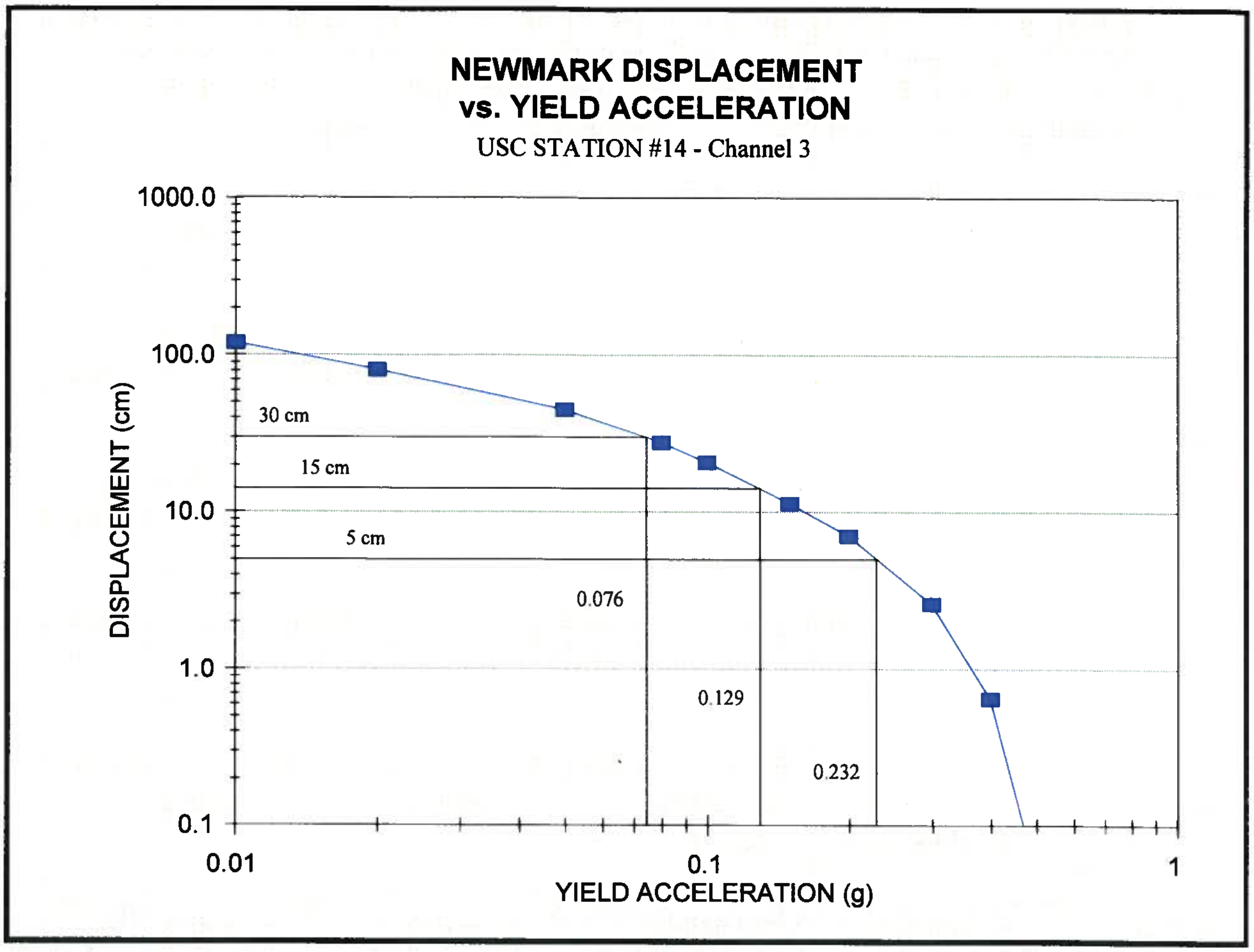

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station #14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.076g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.076g and 0.129g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.129g and 0.232g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.232g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

HOLLYWOOD QUADRANGLE HAZARD POTENTIAL MATRIX													
		SLOPE CATEGORY (% SLOPE)											
Geologic Material Group	**MEAN PHI**	**I 0-14**	**II 14-19**	**III 19-29**	**IV 29-34**	**V 34-40**	**VI 40-47**	**VII 47-53**	**VIII 53-58**	**IX 58-60**	**X 60-70**	**XI 70-78**	**XII >78**
1	40.5	VL	VL	VL	VL	VL	VL	VL	VL	VL	L	M	H
2	33.2	VL	VL	VL	VL	VL	L	L	M	H	H	H	H
3	28.5	VL	VL	VL	L	L	M	H	H	H	H	H	H
4	22.4	VL	VL	L	M	H	H	H	H	H	H	H	H
5	14	L	M	H	H	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Hollywood Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone. H = High, M = Moderate, L = Low, VL = Very Low.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

No earthquake-triggered landslides had been identified in the Hollywood Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a number of relatively small, shallow slope failures in the Hollywood Quadrangle (Harp and Jibson, 1995). Very small landslides attributed to the Northridge earthquake covered a total of approximately one-half of an acre of land in the quadrangle. Of the area covered by these small Northridge earthquake landslides, 86% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by DMG (McCrink and Real, 1996), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).
2. Geologic Strength Group 4 is included for all slopes steeper than 19 percent.
3. Geologic Strength Group 3 is included for all slopes steeper than 29 percent.
4. Geologic Strength Group 2 is included for all slopes steeper than 40 percent.
5. Geologic Strength Group 1 is included for all slopes greater than 60 percent.

This results in approximately 5 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Hollywood Quadrangle.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety.	**299**
CDMG Special Report 152 (Weber and others, 1982)	**19**
Total Number of Shear Tests	**318**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Hollywood 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Department of Conservation
Division of Mines and Geology
***Formerly with DMG, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California Department of Conservation, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage:
http://www.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

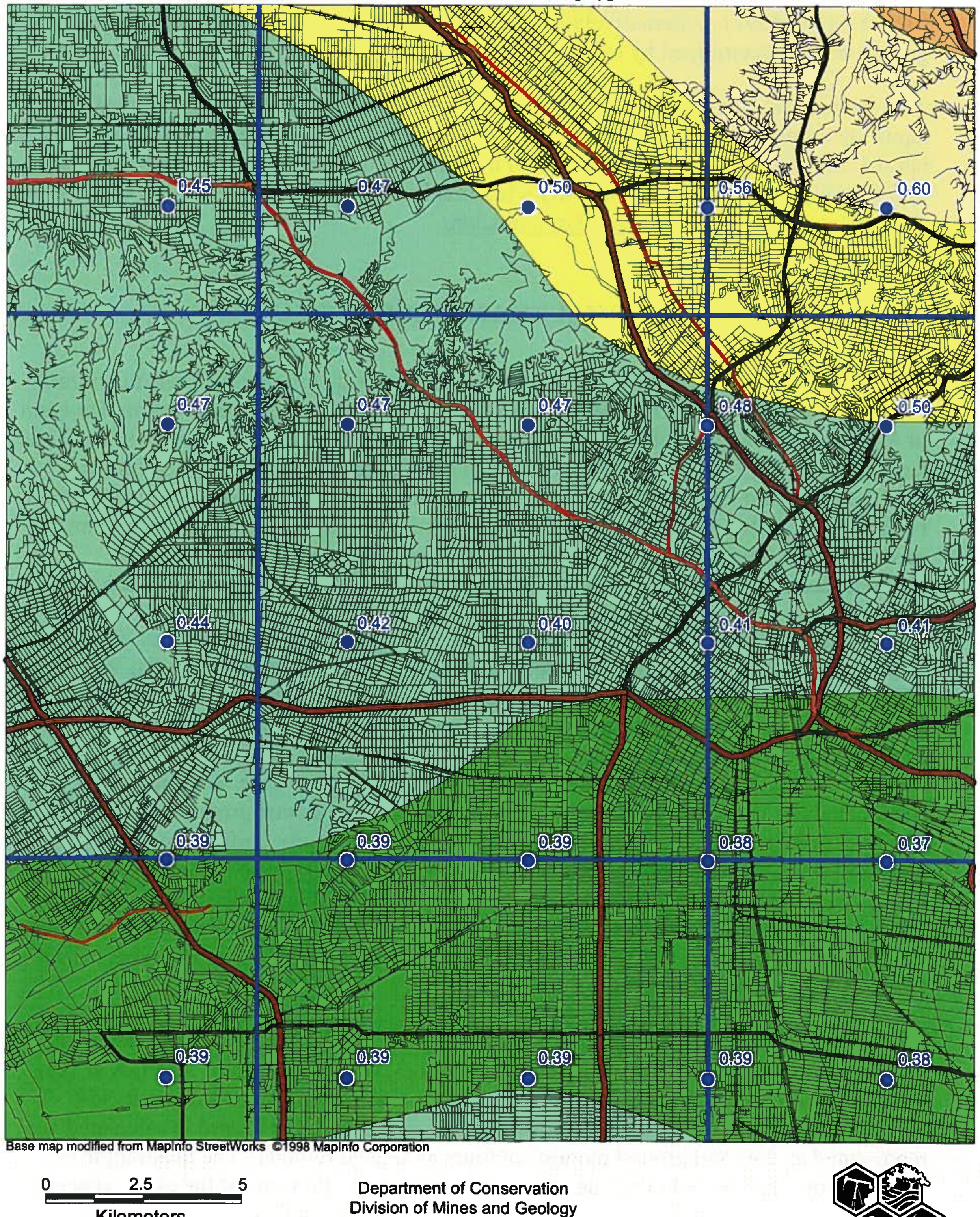
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

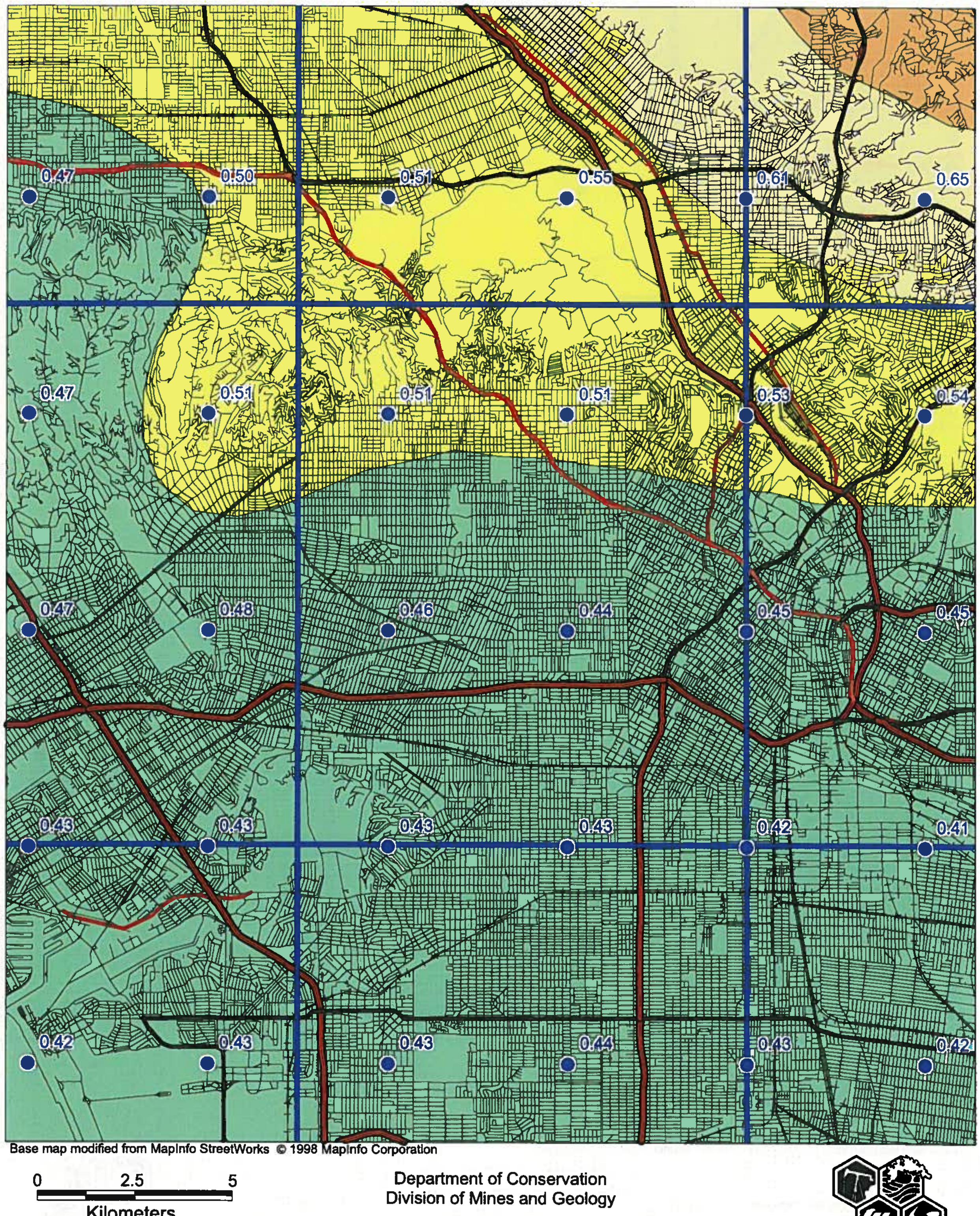
Figure 3.1

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

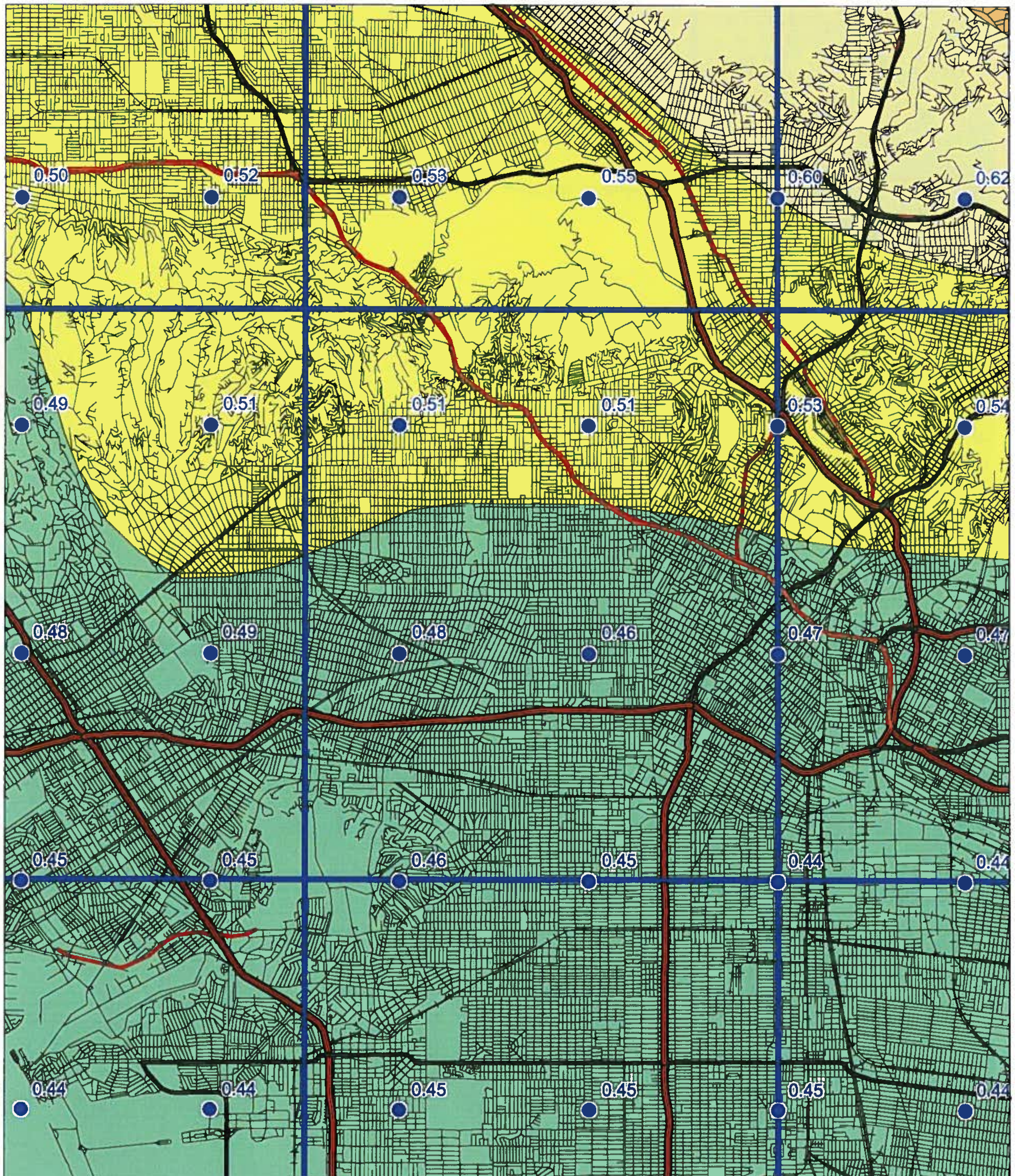
Figure 3.2

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

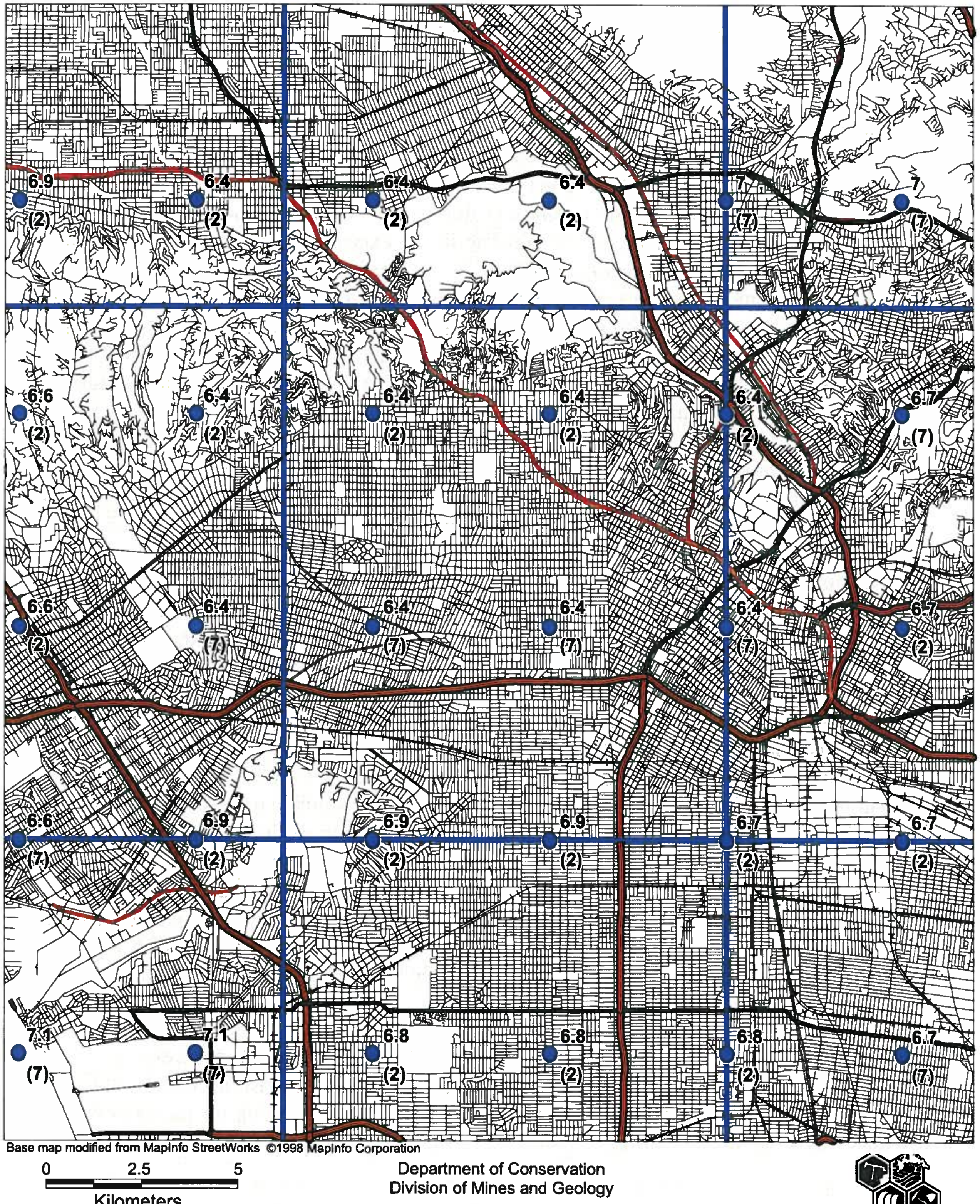
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

HOLLYWOOD 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Department of Conservation
Division of Mines and Geology

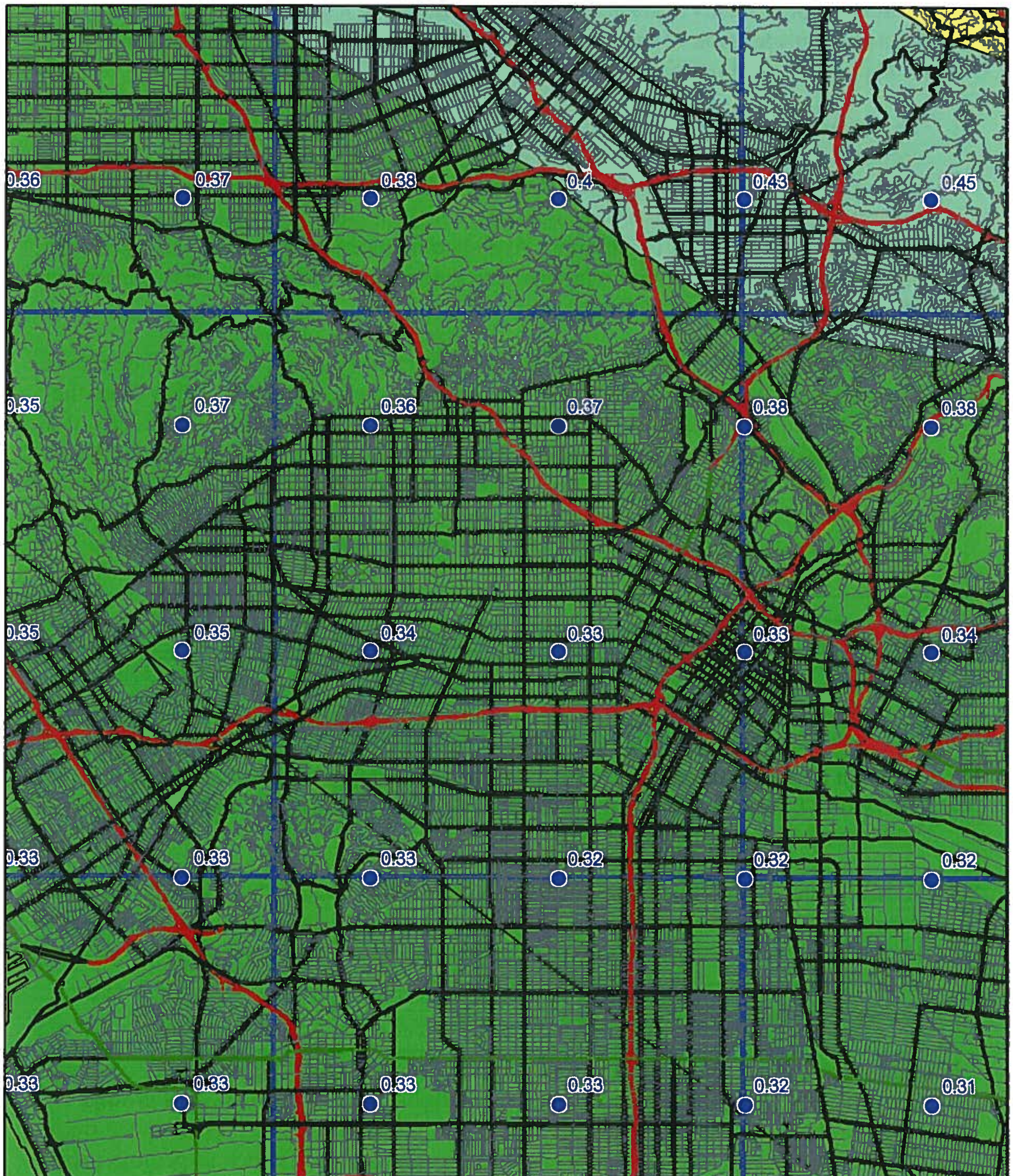
Figure 3.4

HOLLYWOOD 7.5-MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours.*

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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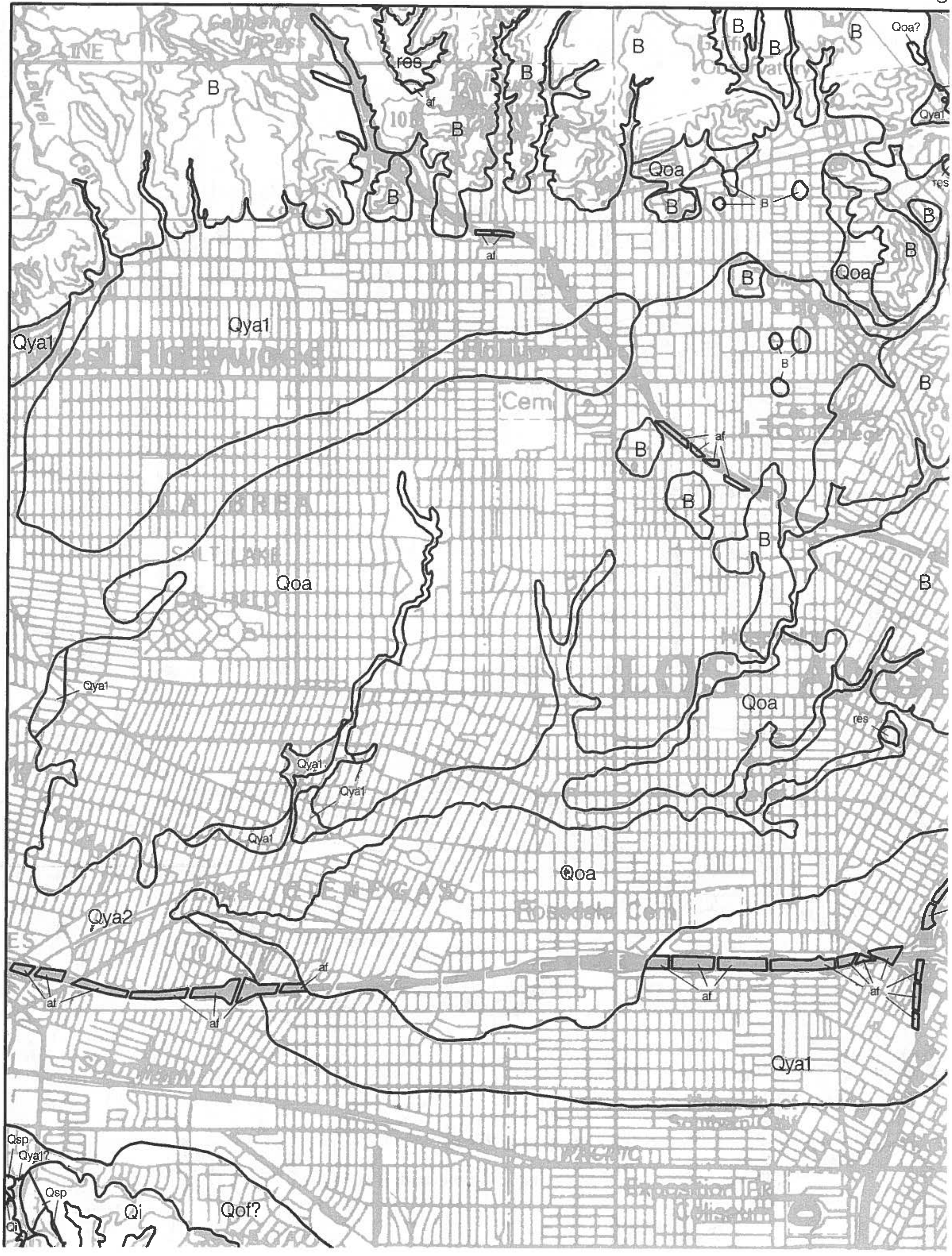

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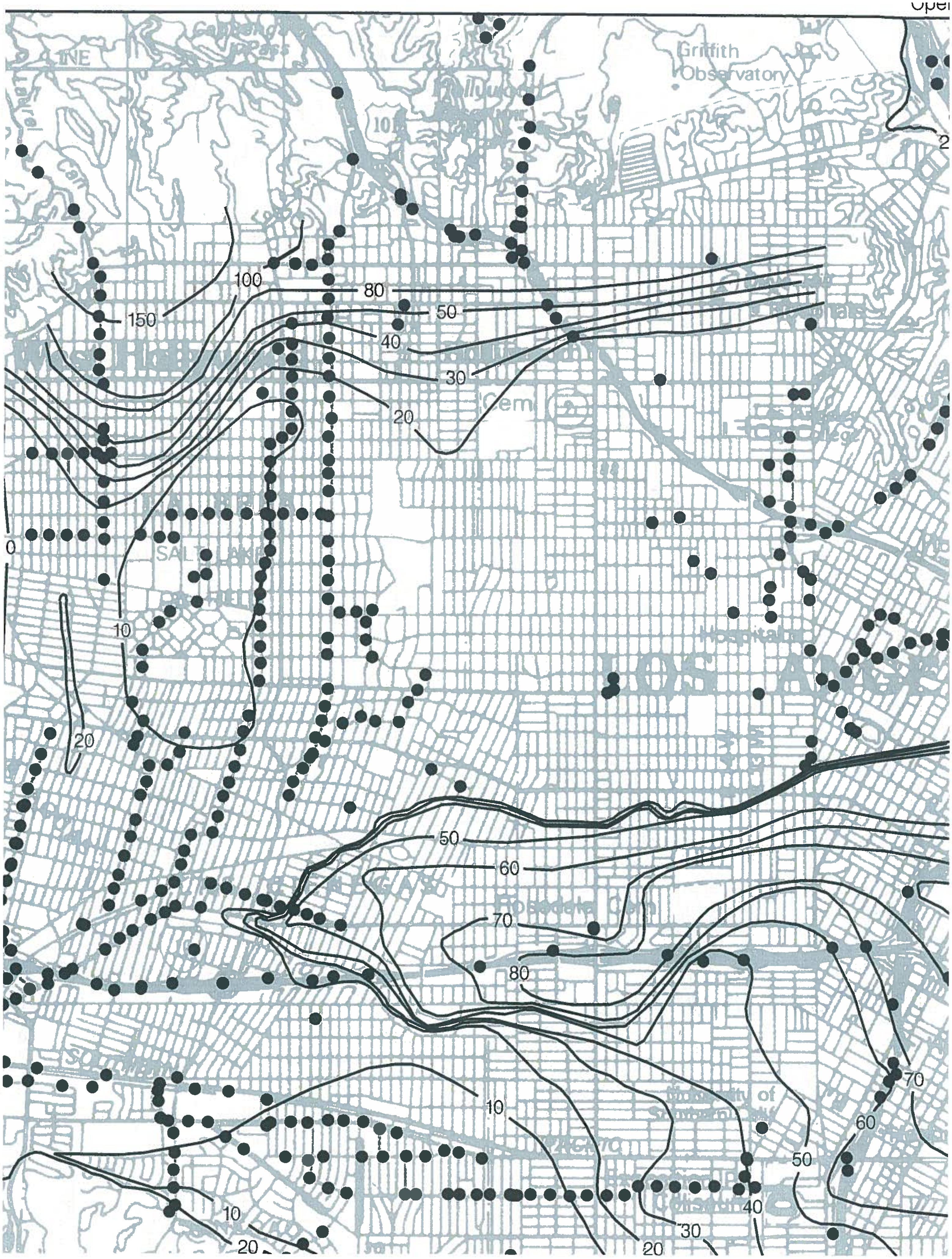

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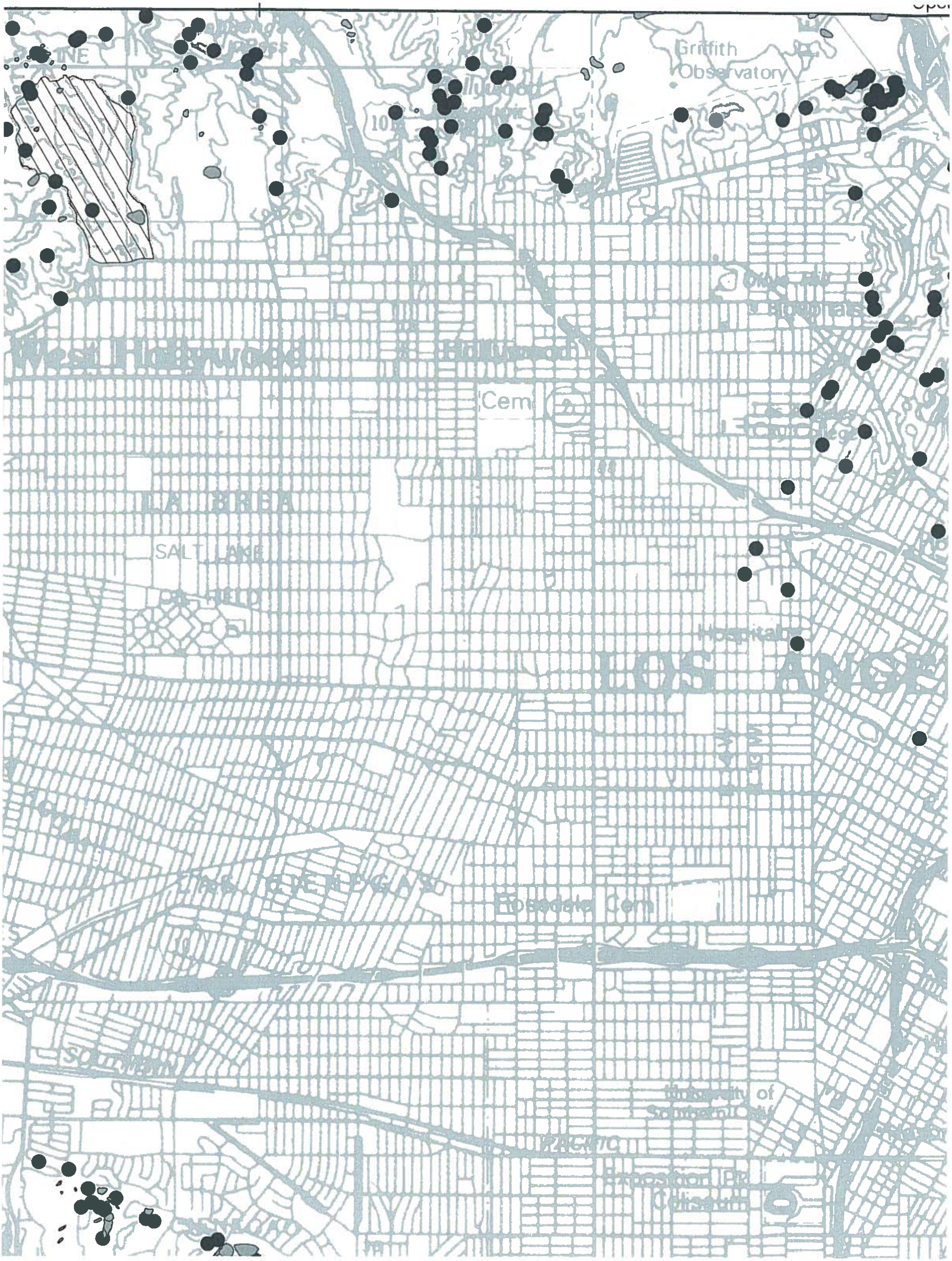
Griffith
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West Hollywood
Hollywood
Cem
LA BREA
SALT LAKE
Hospital
LOS ANGE
Rosedale Cem
University of
Southern Calif
PACIFIC
Exposition Pk
Coliseum

ATTACHMENT E

California Division of Mines and Geology
Fault Evaluation Report FER-173
Northern Newport-Inglewood Fault Zone,
Los Angeles County, California

by

William A. Bryant
Associate Geologist
November 15, 1985

INTRODUCTION

Potentially active faults located in Los Angeles County that are evaluated in this Fault Evaluation Report (FER) form the Newport-Inglewood fault zone and include, from southeast to northwest, the Reservoir Hill, Northeast Flank, Pickler, Cherry Hill, Avalon-Compton, Potrero, and Inglewood and associated faults (figure 1). These faults were zoned for Special Studies in 1976 in the Long Beach, Inglewood, Hollywood, and Beverly Hills 7.5-minute quadrangles (CDMG, 1976a, 1976b, 1976c, 1976d). Zoning for Special Studies in 1976 was based on the criterion of Quaternary-active faulting. Some faults in these quadrangles may not meet the current criteria for zoning and most of the zones appear to be unnecessarily wide. Those faults determined to be sufficiently active (Holocene) and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The Los Angeles County study area is characterized by a tectonic regime dominated by strike-slip faulting along elements of the San Andreas fault system. Topography in the study area is generally subdued, ranging from the flat floodplains of the Los Angeles River and Ballona Creek, to a series of low hills aligned along a general northwest trend. Elevations in the study area range from about 9 meters above sea level in the Los Angeles River to 156 meters in the Baldwin Hills. Development in the study area is extremely heavy; the earliest available aerial photographs (1927) do not predate the extensive oil field development along the Newport-Inglewood fault zone.

Predominant rock types exposed in the study area include lower Pleistocene San Pedro Formation, upper Pleistocene Lakewood Formation, and Holocene alluvium (Poland others, 1956; Poland and others, 1959; CDWR, 1961, 1968; Castle, 1960; DMG, 1982; Randell and others, 1983). Pliocene and Pleistocene marine and non-marine sedimentary rocks underlie the low hills which include (from south to north): Bixby Ranch Hill, Reservoir Hill, Signal Hill, Dominguez Hill, Rosecrans Hills, Baldwin Hills, and Cheviot (Beverly) Hills (figures 2a, 2b, 2c). The Los Angeles River and Ballona Creek have cut the Dominguez and Ballona gaps, respectively, during the last low stand of sea level (17-20 Ka) (Davis, 1981; Poland and others, 1956). These water gaps have subsequently been backfilled with Holocene alluvial floodplain deposits (CDWR, 1961, 1968).

The Newport-Inglewood fault zone extends for about 70 km from Newport mesa northwest to the Cheviot Hills along the western side of the Los Angeles Basin (Barrows, 1974). The Newport-Inglewood fault zone, which was originally zoned for Special Studies in 1976, is re-evaluated in two Fault Evaluation Reports (FER's). The Southern Newport-Inglewood fault zone was evaluated in FER-172. This FER will evaluate segments of the Newport-Inglewood fault zone in the Long Beach, Inglewood, Hollywood, Torrance, and Beverly Hills 7.5-minute quadrangles (figure 1).

The Newport-Inglewood fault zone consists of a series of northwest-trending, generally right-lateral strike-slip faults. Individual faults at or near the surface within the zone form short, discontinuous, generally left-stepping en echelon patterns. Associated northwest-to-west-trending, right stepping anticlinal folds, and numerous short subsidiary normal and reverse faults form what has variously been termed the Newport-Inglewood structural zone (Barrows, 1974), Newport-Inglewood zone of deformation (WCC, 1979), Newport-Inglewood uplift, or the Newport-Inglewood zone of flexure. For purposes of this report, the term Newport-Inglewood fault zone will be used because only those faults at or near the surface will be evaluated.

Harding (1973) considered the Newport-Inglewood fault zone to typify the wrench-tectonic style of deformation. Evidence for wrench deformation cited by Harding includes: (1) laterally offset fold axes and fold flanks; (2) horizontal slickensides observed along faults (well core data); (3) juxtaposed dissimilar stratigraphies; (4) variable nature of fault zone; (5) en echelon fold and fault pattern; (6) strike-slip genesis of associated secondary structures; and (7) parallel trend with documented wrench faults (i.e., San Andreas fault). The relatively small displacements of fold axes and the lack of a through-going fault in the sedimentary cover (Quaternary deposits?) indicated to Harding that the Newport-Inglewood fault zone is in the early stages of structural development (after Wilcox and others, 1973).

The magnitude of right-lateral offset along the Newport-Inglewood fault zone is not well known. Harding (1973) indicated that right-lateral strike-slip displacement of structural axes ranges from 180 to 760 meters. Hill (1971) reported that offsets of Miocene and Pliocene, and Pleistocene lithofacies seem to confirm right-lateral displacements of up to 3 km. Hazenbush and Allen (1958) suggested that the maximum horizontal deformation along the Newport-Inglewood fault zone may total more than 9-1/2 km since middle Miocene time. Woodward-Clyde Consultants (WCC, 1979) estimated that up to 3-1/2 km of right-lateral displacement has occurred along the fault zone since late Miocene time.

WCC (1979) calculated a slip-rate of about 0.5 mm/yr along the southern Newport-Inglewood fault zone, based on correlation of E-log data in the Seal Beach and Huntington Beach oil fields. The 0.5 mm/yr slip-rate represents fault displacement since late Miocene time, and it is not certain how this slip-rate relates to late Quaternary slip-rates. It was found that segments of the Newport-Inglewood fault zone in Huntington Beach, Seal Beach, Long Beach, and the Baldwin Hills are all characterized by long-term slip-rates of about 0.5 mm/yr (Guptill and Heath, 1981). It was also concluded that the ratio of horizontal slip to vertical slip was about 20:1 (WCC, 1979).

Clark and others (1984) assigned a preferred late Quaternary slip-rate of about 0.6 mm/yr along the North Branch fault in the Bolsa gap area. Clark and others emphasized that there were significant to major uncertainties involved with the estimates of maximum slip along the fault. It was also noted that the slip-rate is based on apparent vertical separation of the Holocene Bolsa aquifier; horizontal slip is not known.

RESERVOIR HILL FAULT

The Reservoir Hill fault, a N50°W-trending, right-lateral strike-slip fault, was zoned for special studies in 1976 based on mapping by Poland and others (1956) (figure 2a). Poland and others described the fault as a steeply northeast-dipping normal fault, based on oil well E-logs, and a northeast-facing scarp in late Pleistocene Lakewood Formation. The top of the lower Pleistocene San Pedro Formation is offset about 85 meters (down to the east), and the fault offsets late Pleistocene Lakewood Formation, according to Poland and others. The Reservoir Hill fault is thought to be a northwest continuation of the Seal Beach fault (Poland and others, 1956; Barrows, 1974; Bryant, 1985). Ingram (1968) did not map the Reservoir Hill fault in the Long Beach oil field, perhaps because the fault is located near the edge of the oil field. However, proprietary oil field data indicates that the Reservoir Hill fault is a major structural feature (D.D. Clarke, p.c., Sept. 1985). Ziony and others (1974) classified the Reservoir Hill fault as late Quaternary active.

Several site investigations along the Reservoir Hill fault have yielded conflicting data regarding the location and recency of faulting. A report for the Long Beach Community Hospital (Egner and others, 1974) reported no evidence of faulting and stated that it was doubtful that the northeast-facing scarp was fault related (locality 1, figure 2a).

Merrill (1977) mapped a northwest trending fault in late Pleistocene deposits, but stated that Holocene deposits were not offset. However, Merrill did not describe the Holocene deposits nor was the relationship between the fault and Holocene soil described (figure 2a, Table 1).

Johnson and Brown (1984) exposed evidence of a significant fault offsetting lower Pleistocene San Pedro Formation against upper Pleistocene Lakewood Formation (figures 2a, 4, Table 1). The main fault, located near the base of the northeast-facing scarp, trends N55°W and dips 87°SW, and has a component of down-to-the-east normal displacement. Although prior grading of the site had removed natural soils, the consultant concluded that the age of faulted Lakewood Formation deposits could be as young as 15,000 ybp. Sand dikes and sand boils exposed in the exploratory excavations indicate previous seismicity that is possibly associated with the Reservoir Hill fault. Johnson and Brown stated that the Reservoir Hill fault forms a ground water barrier in Holocene deposits in Alamitos gap (San Gabriel River floodplain; see Bryant, 1985).

Two site investigations at the southeast end of Reservoir Hill, which is a pressure ridge, exposed evidence of late Pleistocene offset along the Reservoir Hill fault (Scullin and Simon, 1984 and Rodine and McNamara, 1984) (figure 2a, Table 1). The Scullin and Simon investigation exposed fractures in pre-1933 fill that were on trend with the Reservoir Hill fault. These fractures conceivably could indicate surface fault rupture associated with the 1933 Long Beach earthquake. The fractures were not associated with faults in the natural deposits exposed. However, caving in the area where the faults were expected to be observed precluded detailed examination of the exposure. The consultant concluded that the fractures in fill were not surface fault rupture features.

The site investigation by Rodine and McNamara exposed the prinicpal trace of the Reservoir Hill fault (figure 2a, Table 1). The consultant concluded that the fault did not offset latest Pleistocene Lakewood Formation and the hazard of surface fault rupture was very low at the site. However, controversy exists regarding the identification of unfaulted material overlying the Reservoir Hill fault. D.D. Clarke, City of Long Beach geologist, contends that the unfaulted material is old fill derived from the Lakewood Formation and that it is possible that this fill could be offset. Thus, if the unfaulted unit has been misidentified, then evidence of a lack of Holocene faulting has not been demonstrated.

Permissive evidence of Holocene active faulting along the Reservoir Hill/Seal Beach fault was demonstrated at Landing Hill by Davis (1981) (refer to Bryant, 1985).

NORTHEAST FLANK AND PICKLER FAULTS

The Northeast Flank and Pickler faults were zoned for special studies in 1976 based on mapping by Poland and others (1956) (figure 2a). The Northeast Flank fault was inferred by Poland and others (1956), based on a northeast-facing scarp in late Pleistocene deposits along the northeast flank of Signal Hill (figure 2a) and unspecified water-well data. Poland and others assumed that the Northeast Flank fault was a steeply southwest-dipping fault, based on oil well data from Stolz (1943). Poland and others indicated that the base of the lower Pleistocene Silverado zone (San Pedro Formation) was vertically offset about 61 meters. Ingram (1968) mapped the fault as a steeply southwest-dipping reverse fault (figure 2a).

The Pickler fault (figure 2a) was first mapped by Stolz (1943), who inferred the fault as a south-dipping reverse fault. Poland and others (1956) mapped the fault based on a marked difference in the productivity of oil wells on either side of the fault and by a "known discontinuity in the principal water-bearing zones" (specific deposits not mentioned). Vertical displacement of the base of the San Pedro Formation was thought by Poland and others to be about 46 meters.

Ziony and others (1974) classified both the Northeast Flank and Pickler faults to be late Quaternary active.

CHERRY HILL FAULT

The Cherry Hill fault was zoned for special studies in 1976 based on the mapping of Poland and others (1956) (figure 2a). Poland and others stated that the Cherry Hill fault was the most clearly defined fault along the southern Newport-Inglewood fault zone. The Cherry Hill fault, first mapped by Stolz (1943), is considered by Poland and others to be a steeply northeast-dipping reverse fault. Poland and others mapped the Cherry Hill fault as offsetting upper Pleistocene deposits. Vertical displacement of Miocene beds is about 305 meters and vertical displacement of the base of the lower Pleistocene San Pedro Formation was reported to be about 61 meters, based on water-well data (Poland and others, 1956). Poland and others stated that vertical displacement of the late Pleistocene land surface totals as much as

33 meters (down to the southwest). An unspecified strike-slip component of offset occurs along the Cherry Hill fault, according to Poland and others. Ingram (1968) indicated that about 915 meters of right-lateral displacement occurs in Miocene sedimentary rocks at a depth of about 1220 meters (figure 2a).

Poland and others mapped the Cherry Hill fault as concealed across the floodplain of the Los Angeles River (Dominguez gap). Poland and others stated that a hydraulic discontinuity in lower Pleistocene deposits indicated faulting in Dominguez gap. However, their was no geologic evidence of faulting in recent (Holocene) deposits in Dominguez gap (Poland and others, 1956). Ziony and others (1974) classified the Cherry Hill fault as late Quaternary active.

Many site-specific fault investigations have been conducted in the general vicinity of the Cherry Hill fault since it was zoned in 1976, but most of these reports provide minimal information regarding the location of the fault because trenching was generally shallow. In addition, some near-surface units within the Lakewood Formation are very massive, and it is often difficult to distinguish between Lakewood Formation and younger colluvial deposits derived from the Lakewood Formation. Those investigations that have trenched very near or across the Cherry Hill fault have been plotted on figure 2a and summarized in Table 1.

Evans (1977) (included as appendix to Scullin, 1979-AP-1572) trenched across the mapped trace of the Cherry Hill fault and reported no evidence of faulting in late Pleistocene Lakewood Formation. Although the trench logs are too generalized to document lack of recent faulting, at station 0 + 76 in T-2, a step or offset in the contact between the Palos Verdes Sand member of the Lakewood Formation and overlying older alluvium (paleosol?) is suggestive of recent faulting (locality 2, figure 2a). This feature is along a N30°W trend with faults reported by Scullin (1979a) (locality 2, figure 2a).

Scullin (1979a) observed faults in late Pleistocene deposits along the trend of the Cherry Hill fault at locality 2 (figure 2a). Scullin did not recommend a building setback because he reported that upper Lakewood terrace deposits were not offset. Although the trench logs are very generalized, a significant amount of deformation in the upper Lakewood Formation (paleosol?) is apparent. In addition, the soil/colluvium unit significantly thickens across the fault, suggesting possible Holocene displacement.

Two other site investigations (Scullin, 1979c; Cousineau, 1983) indicate significant deformation of late Pleistocene deposits just east of the Cherry Hill fault (figure 2a, Table 1).

Dominguez Hill is a northwest-trending dome (locality 3, figure 2a). The Cherry Hill fault approaches Dominguez Hill from the southeast, and the southern part of the Avalon-Compton fault is located near the northwest flank of Dominguez Hill (figures 2a, 2b). Although reverse-oblique and strike-slip faulting have been reported at depth beneath Dominguez Hill (Grinsfelder, 1943; Graves, 1954), no through-going surface fault is known (Barrows, 1974). Barrows did observe minor south-dipping reverse faults in Plesitocene deposits near locality 4 (figure 2a). Although overlying soil deposits were not offset by these faults, the trend and style of faulting is consistent with a left-stepping, right-lateral strike-slip fault zone. Other minor reverse and oblique-slip faults also may exist within the Dominguez Hills area.

AVALON-COMPTON FAULT

The Avalon-Compton fault was zoned for special studies in 1976, based on mapping by Poland and others (1959) (figure 2b). This N24°W-trending fault was inferred by Poland and others, based on a west-facing scarp and an apparent vertical displacement of about 9 meters of lower Pleistocene deposits (water table levels in Silverado zone).

Ziony and others (1974) classified the Avalon-Compton fault as late Quaternary active.

A site investigation by Ruff and Hannan (1984) exposed evidence of a significant fault about 107 meters east of Poland and others' (1959) inferred fault (locality 5, figure 2b, figure 5, Table 1). The main fault (fault attitude N20°W90°) offsets late Pleistocene deposits identified as Lakewood Formation (figure 5). Major stratigraphic discontinuity across the principal fault and oblique and near-horizontal striations along the fault plane indicate a significant component of strike-slip displacement. Minor drag folds indicate a component of down-to-the-southwest, vertical displacement. Recency of faulting could not be established because natural soils had previously been removed due to grading. However, the consultant recommended a building setback.

ROSECRANS HILLS AREA

Ziony and others (1974) inferred a west-northwest-trending fault near Gardena, based on an 1896 topographic map and a description by Taber (1920, p. 140) (figure 2b). Taber described several closed depressions near the trend of this inferred fault. However, Taber (1920) did not provide a map of these features nor did he cite any other evidence for faulting. Smith (1978) concluded that this fault was based on indistinct, rather broad topographic features not necessarily related to faulting and is highly speculative.

Poland and others (1959) did not map a surface fault in late Pleistocene deposits in the Rosecran Hills area north of the Avalon-Compton fault (figure 2b). Poland and others indicated that a northwest-trending shear zone is located at depth beneath the Rosecrans Hills, but that beds of the lower Pliocene Repetto Formation do not appear to be offset. California Department of Water Resources (CDWR, 1961) stated that Pleistocene deposits are anticlinally folded in the Rosecrans Hills. The Rosecrans Hills area lies between two left-stepping segments of the Newport-Inglewood fault zone, the Avalon-Compton, and Potrero faults (figures 1, 2b).

POTRERO FAULT

The Potrero fault was zoned for special studies in 1976, based on mapping by Poland and others (1959) and Castle (1960) (figures 2b, 2d). Poland and others mapped the fault based on a 15-meter-high, southwest-facing scarp in late Pleistocene deposits, a 30-meter vertical displacement of lower Pleistocene deposits (Silverado zone), and a groundwater barrier in unspecified Pleistocene deposits. Castle's faults locally were based on Poland and others (1959), but significant differences in detail exist (figures 2b, 2d). Willis and Ballantyne (1943) mapped a N25°W-trending 82°SW-dipping fault, based on oil field data. At a depth of about 915 meters, Willis and Ballantyne reported that the Potrero fault vertically offsets Pliocene Repetto Formation about 82 meters (down to the southwest). However, Willis and

Ballantyne reported that the horizontal (strike-slip) component of offset along the Potrero fault was more signficant. The axis of the anticlinal fold in the Potrero oil field has been right-laterally offset at least 365 meters, and the predominant sense of offset indicated by striations along fault planes recovered in drill cores is horizontal.

Poland and others (1959) and Castle (1960) inferred several cross-faults that presumably offset the trace of the Potrero fault (figures 2b, 2d). These faults will be evaluated in a separate section in this Fault Evaluation Report.

Kew (1923) mapped the Potrero fault (figure 2d) that in general agrees with the location of the fault mapped by Poland and others (figure 2b) although Kew did not map the east-northeast-trending cross-faults that presumably offset the Potrero fault. Kew cited evidence of recent faulting along the Potrero fault that included: (1) Pleistocene deposits abruptly truncated against alluvium at "the old Centinela Spring" (locality 6, figure 2d); (2) right-lateral deflection of a drainage south of Centinela Creek (locality 7, figure 2d); (3) Centinela Creek has been beheaded. Kew stated that no evidence of historic surface fault rupture has been observed along the Potrero fault.

Two site-specific fault investigations have been conducted near the Potrero fault, but no evidence of faulting was reported (figure 2b, Table 1). Additional fault investigations within the SSZ's have been performed, but are not discussed in this FER.

EAST-NORTHEAST-TRENDING CROSS FAULTS

Poland and others (1959) and Castle (1960) mapped six cross-faults that they show offsetting the Potrero fault (figures 2b, 2d). These inferred faults were zoned for special studies in 1976, based primarily on Castle (1960). From south to north these faults are: Century Boulevard, Manchester Avenue, Inglewood Park Cemetery, Centinela Creek, Fairview Avenue, and Slauson Avenue faults (figure 2b). Poland and others (1959) inferred these faults, based on apparent offsets of the ground surface, linear drainages, and apparent offsets of the groundwater table. Water-well control for these faults is very poor, and most do not have substantiating geologic evidence (Poland and others, 1959).

Several site-specific investigations have been conducted across these cross-faults (figure 2b, Table 1). These investigations, though sometimes inadequate, have not verified the existence of any of the cross-faults.

INGLEWOOD FAULT ZONE

The Inglewood fault zone was zoned for special studies in 1976, based on mapping by Poland and others (1959) and Castle (1960) (figures 2b, 2c, 2d). The Inglewood fault zone is a complex, approximately N20°W-trending zone of strike-slip and normal faults. To facilitate discussion, the fault zone will be evaluated in three segments: faults south of the Baldwin Hills, faults within the Baldwin Hills, and faults north of the Baldwin Hills (figures 2b, 2c).

South of Baldwin Hills

Poland and others (1959) inferred the southern segment of the Inglewood fault zone (Townsite fault), based on topographic evidence (subtle southwest-facing break in slope), and an apparent 30-meter vertical displacement of the base of the lower Pleistocene San Pedro Formation (figure 2b). Willis and Ballantyne (1943) mapped the Townsite fault at depth and considered displacement to be primarily strike-slip with a reverse component, based on oil well data. Kew (1923) mapped a segment of the Inglewood fault zone (figure 2d) that corresponds in general to the fault mapped by Poland and others (1959) (figure 2b). Ziony and others (1974) do not depict this fault segment (figure 1).

Baldwin Hills Area

The Inglewood fault zone in the Baldwin Hills mapped by Castle (1960) is a complex, northwest-trending zone of normal and strike-slip faults (figures 2b, 2c). Poland and others (1959) stated that the Inglewood fault formed the east side of a graben that cuts across the center of the Baldwin Hills. Poland and others postulated that about 84 meters of vertical displacement has occurred along this fault, based on the apparent offset of the topographic surface. Most of the faults in the Baldwin Hills mapped by Poland and others were based on unpublished mapping by G.B. Moody (1935).

Driver (1943) considered the Inglewood fault to have a major strike-slip component of offset, based on the configuration of oil-producing horizons, near horizontal striae on fault planes observed in drill cores, and the apparent right-laterally offset northern slope of the Baldwin Hills.

Mapping by Castle and Yerkes (1976) along the Inglewood fault zone does not differ significantly with mapping by Castle (1960). Castle and Yerkes postulated that right-lateral strike-slip displacement along the Inglewood fault zone during Quaternary time may be as much as 610 meters. This displacement is based on the apparent right-lateral deflection of the northern front of the Baldwin Hills.

Numerous faults mapped by Castle (1960) in the Baldwin Hills were zoned for special studies in 1976 (figures 2b, 2c). Most of these faults are inferred and presumably are secondary in nature and are related to uplift and folding in the Baldwin Hills. Little is known about the style of faulting and magnitude of displacement of these features. Most of these faults were zoned in 1976 because they offset Pleistocene deposits, but none are known to have evidence of Holocene displacement. However, some faults mapped by Castle (1960) and Castle and Yerkes (1969), and zoned in 1976, have had historic surface rupture (figures 2b, 2d). Although most of these features are faults, Castle and Yerkes (1976) preferred to call them "earth cracks". These cracks are generally delineated by single or en echelon ruptures of the ground surface along fairly straight, northerly trends. Displacement along the cracks is generally dip-slip, although open fissures with no discernible displacements have been reported. Cumulative dip-slip displacements along cracks range from barely perceptible to approximately 17-1/2 cm (CDWR, 1964; Castle and Yerkes, 1976). Very minor components of left-lateral offset have been reported along some of the cracks (Castle and Yerkes, 1976). The most notable surface rupture event resulted in the failure of the Baldwin Hills dam on December 14, 1963 (CDWR, 1964). CDWR (1964) and Castle and Yerkes (1976) concluded that surface rupture associated with these faults and fault-like features is largely the result of subsidence caused by fluid withdrawal in the

Inglewood oil field. Site-specific fault investigations have not verified those faults away from the Inglewood fault zone that are not associated with fluid withdrawal (figure 2b, Table 1).

Faults North of Baldwin Hills

Poland and others (1959) mapped a N26°W-trending fault north of the Baldwin Hills that was zoned for special studies in 1976 (figure 2c). Poland and others mapped this northwest continuation of the Inglewood fault zone as concealed through the Ballona Creek floodplain (Ballona gap). Their interpretation was based on water-well data indicating vertical displacement of Pleistocene water-bearing deposits of about 60 meters. The down-to-the-east sense of offset is opposite to the displacement mapped in the Baldwin Hills. Poland and others indicated that the "50-foot gravel" horizon (early Holocene) is not offset along the fault (not a ground water barrier). North of Ballona Gap, Poland and others apparently inferred the surface trace of the fault based on topographic evidence in the Cheviot Hills. Poland and others inferred the Inglewood fault as offsetting late Pleistocene deposits in the area south of Olympic Drive (locality 8, figure 2c).

Crowder (1968) postulated that the Inglewood fault in the Cheviot Hills is a southwest-dipping normal fault, although the magnitude of displacement is not known. The Inglewood fault zone is quite close to the east-west-trending Santa Monica fault zone (figure 1), and it is assumed by this writer that the complexities associated with converging fault zones result in distributive, discontinuous faulting in the near surface along the Inglewood fault zone.

The Ballona Creek floodplain east of the Inglewood fault historically had been a marshland until dewatering operations began (Weber and others, 1982). Trench excavations by D. Moran (p.c., Oct. 1985) exposed carbonaceous deposits indicative of marshy conditions at locality 9 (figure 2b). Radiocarbon dates of carbonaceous deposits at depths of 2 meters and 2.7 meters were 2,000 ybp and 4,000 ybp, respectively. Thus, the westward flow of Ballona Creek has been impeded during the Holocene, possibly due to surface faulting along the Inglewood fault zone (Weber and others, 1982).

Two site specific fault investigations near the northern end of the Inglewood fault zone did not report evidence of late Pleistocene faulting (figure 2c, Table 1).

FAULT A

Poland and others (1959) mapped a west-northwest-trending fault along the northern front of the Baldwin Hills. This fault was also mapped by Castle (1960) and was zoned for special studies in 1976, based on Castle (1960) (figure 2b). The style of faulting and magnitude of displacement are not known for this fault. Castle (1960) and Poland and others (1959) depict this fault as offsetting Tertiary sedimentary rocks, but not alluvium.

Weber and others (1982) based all of their faults in the Baldwin Hills on Castle and Yerkes (1976), except for Fault A. Weber and others (1982) mapped this fault as offsetting Holocene alluvium at locality 10 (figure 2b). The fault mapped by Weber and others differs significantly in location from the fault mapped Poland and others (1959) and Castle (1960) (figure 2b).

FAULT B

A northwest-trending fault in Ballona Creek mapped by Castle (1960) was zoned for special studies in 1976 (figure 2b). Castle (1960) based the location of this fault on the anomalous presence of Pleistocene sands in the floodplain of Ballona Creek (locality 10, figure 2b) and apparent lithologic discontinuities in unspecified alluvium, based on water-well data. Ziony and others (1974) classified this fault as Holocene active, based on mapping by Castle (1960).

D. Moran (p.c. October 1985) currently is investigating the southeastern projection of Fault B at locality 9 (figure 2b) for the City of Los Angeles. No evidence of faulting was observed in 6,000-year-old alluvium, based on trench excavations. In addition, an approximately 10 1/2-meter-deep, 114-meter-long tunnel excavation exposed unfaulted late Pleistocene alluvium (D. Moran, p.c. October 1985; J. Kahle, p.c. October 1985). Moran (p.c. October 1985) stated that geomorphic evidence for this fault was generally vague southeast of the Pleistocene deposits at locality 10 and only vague tonal lineaments suggested the location of the fault (figure 2b).

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the Los Angeles County study area was accomplished using Fairchild aerial photos (C-113, 1927, scale 1:18,000; C-300, 1928, scale 1:18,000).

Field mapping in the study area is severely limited by intense development throughout almost all of the study area. Therefore, most of the interpretation of air photos was not field checked. The author spent about 1/2 day examining exposures of the Reservoir Hill fault at the Rodine and McNamara (1984) site (figures 2a, 3a). Observations of excavations were made by J. Kahle at the D. Moran site (locality 9, figure 2b). Results of air photo interpretation by this writer are summarized on figures 3a, 3c. The air photos also were reviewed by E. Hart, who largely verified the interpretations and provided additional observations.

RESERVIOR HILL, NORTHEAST FLANK, PICKLER, AND CHERRY HILL FAULTS

Faults in the Long Beach 7.5-minute quadrangle will be discussed together in order to better portray the signficant pattern of recent faulting (figure 3a). From southeast to northwest, the Reservoir Hill, Northeast Flank, and Cherry Hill faults form a left-stepping en echelon pattern of faulting characteristic of right-lateral strike-slip displacement (figure 3a). Reservoir Hill and Signal Hill are pressure ridges located between left-stepping segments of the Newport-Inglewood fault zone. These faults are associated with relatively broad warping of what Poland and others (1956, 1959) considered to be a late Pleistocene terrace surface, much of which is still preserved. Pleistocene deposits offset along these faults are soft and easily erodable; thus, the geomorphic expression of recently active faulting is generally quite subtle.

The Reservoir Hill fault is a northwest-trending fault that generally is moderately well-defined. The fault trace mapped by Poland and others (1956) and zoned in 1976 was generally verified by this writer (figures 2a, 3a). Geomorphic features indicative of recent faulting along the Reservoir Hill fault include a moderately well-defined, northeast-facing scarp in Pleistocene deposits, a linear trough, left-laterally deflected drainage (stream capture?), a possible right-laterally deflected drainage, and associated tonal lineaments in late Pleistocene deposits (figure 3a). Just southeast of the study area, this fault is associated with a linear trough, possible closed depression, and associated tonal lineaments in Holocene alluvium (refer to figure 3b of Bryant, 1985).

The Northeast Flank fault strikes northwest from the northwest side of Reservoir Hill and is located along the northeastern flank of Signal Hill (figure 3a). The ground surface along much of the Northeast Flank fault has been modified by oil field grading, based on air photo interpretation of 1927 and 1928 Fairchild air photos. However, the fault is delineated by a moderately defined, northeast-facing scarp that aligns with a southwest-facing scarp along the west side of Reservoir Hill (figure 3a). This writer could not verify the southeastern extent of the fault mapped by Poland and others (1956). To the northwest, the fault may bend west around the northern slope of Signal Hill, probably as a reverse fault (Pickler fault?) (locality 11, figure 3a). However, a well-defined, northwest-facing scarp along the trace of the Pickler fault was not observed by this writer, based on air photo interpretation.

The Cherry Hill fault is a moderately well-defined fault trending northwest from the west side of Signal Hill (figure 3a). The fault is delineated by a moderately well-defined, though somewhat dissected, southwest-facing scarp in late Pleistocene deposits (figure 3a). A right-laterally deflected drainage, closed depression(?), and associated tonal lineaments suggest latest Pleistocene to Holocene strike-slip faulting (figure 3a). The late Pleistocene terrace surface east of the fault has been warped and tilted eastward, suggesting that folding associated faulting has occurred, and is probably continuing to occur, along this segment of the Cherry Hill fault. A component of recent vertical displacement is suggested at locality 12 (figure 3a) where a terrace surface seems to be vertically offset (southwest side down). Near this location the Cherry Hill fault changes to a more northerly trend before it approaches late Holocene alluvium of the Los Angeles River floodplain (Dominguez gap) (figure 3c). The northwest continuation of the Cherry Hill fault is suggested by a wide zone of vague tonal lineaments in late Holocene alluvium across Dominguez gap (figure 3a). Associated geomorphic features were not observed in Dominguez gap, although it is not expected that ephemeral, fault-related geomorphic features would be preserved for any length of time in such a relatively high-energy/depositional environment.

AVALON-COMPTON, POTRERO, AND INGLEWOOD FAULTS

The pattern of left-stepping, en echelon strike-slip faults is consistent from the Cherry Hill fault to the Avalon-Compton fault (figures 1, 3a, 3b). Dominguez Hills, a compressional structure situated between two left-stepping segments of the Newport-Inglewood fault zone, is a broadly arched, late Pleistocene terrace surface (figure 3a). The relative lack of dissection across the late Pleistocene surface of Dominguez Hills suggests very recent tectonic deformation. However, there is no geomorphic evidence of a through-going fault zone across Dominguez Hills.

The Avalon-Compton fault is a moderately well-defined, N24°W-trending strike-slip fault (figure 3b). The fault is delineated by a moderately well-defined, southwest-facing scarp in late Pleistocene deposits. Additional geomorphic features suggesting latest Pleistocene to Holocene strike-slip displacement include right-laterally deflected drainages, linear troughs in late Pleistocene deposits, closed depressions(?), and associated tonal lineaments (figure 3b). The inferred fault mapped by Poland and others (1959) was only partly verified by this writer along the southeastern part of the fault (figures 2b, 3b). The fault mapped in this study, and verified by Ruff and Hannan (1984), is located from 105 to 210 meters east of the inferred fault zoned in 1976 (figures 2b, 3b).

Recent faulting in the Rosecrans Hills area previously had not been recognized. An inferred west-northwest-trending fault mapped by Ziony and others (1974) (figure 2b) was not verified by this writer. However, short, left-stepping features located between the Avalon-Compton and Potrero faults are consistent with the overall structural fabric of the Newport-Inglewood fault zone (locality 13, figure 3b). Geomorphic features delineating recently active strike-slip faulting are generally only moderately defined along these two inferred faults and could be erosion along a fault or joints in late Pleistocene deposits.

The Potrero fault is delineated by a moderately well-defined, southwest-facing scarp in late Pleistocene deposits that appears to offset a largely preserved terrace surface (figure 3b). Associated geomorphic features indicating latest Pleistocene to Holocene strike-slip displacement (with a normal, down-to-the-west component of displacement) include right-laterally deflected and vertically offset drainages, closed depressions, a linear trough in late Pleistocene deposits, and associated tonal lineaments (figure 3b). The Potrero fault mapped by Poland and others (1959) and Castle (1960) generally was verified by this writer, although differences in detail exist (figures 2b, 3b). Specifically, the cross-faults mapped by Poland and others (1959) and Castle (1960) are not well-defined, and the drainages used to locate the east-northeast-trending faults are not necessarily linear and are more easily explained as drainages in the process of dissecting the southwest-facing Potrero fault scarp. No geomorphic evidence of these cross-faults was observed by this writer southwest of the Potrero fault. No evidence was observed that the Potrero fault is offset by these inferred cross-faults (figure 3b). The Townsite fault of Poland and others (1959) and Kew (1923) generally is not well-defined and could not be verified by this writer except in the vicinity of locality 14 (figure 3b).

The Inglewood fault zone consists of both left- and right-stepping segments generally delineated by moderately well-defined, southwest-facing scarps (figure 3b). Both right-lateral strike-slip and normal displacement during latest Pleistocene and, possibly, Holocene time are suggested by faceted spurs, right-laterally deflected drainages, a possible offset alluvial fan (Holocene ?), and linear drainages (figure 3b). Significant modification of the ground surface by oil field grading had occurred prior to the earliest available air photo coverage (1927), so it is difficult to evaluate the youthfulness of some of these geomorphic features. Also, the fault in the Baldwin Hills is not as well defined in relation to the fault segment just south of the Baldwin Hills. The complex zone of faulting and cross-faults defining the Inglewood fault zone mapped by Castle (1960) and Castle and Yerkes (1976) was not verified by this writer, based on air photo interpretation (figures 2b, 3b). If the northeast-trending faults that are depicted as offsetting segments of the Inglewood fault exist, they are probably minor features because they are not well-defined. Additional north and northeast-trending faults mapped by Castle (1960) and zoned for special studies in 1976 are not well-defined and could not be verified by this writer, based on air photo interpretation (figures 2b, 2c, 3b). Also, the vague tonal lineaments reported by D. Moran (p.c., October 1985) generally were not verified by this writer.

North of the Baldwin Hills, tonal lineaments and a west-facing scarp in Holocene alluvium indicate that the Inglewood fault zone extends north of the Baldwin Hills and is probably Holocene active (figures 3b, 3c). However, the fault mapped by Poland and others (1959) northwestward into the Beverly Hills area was only partly verified by this writer (figures 2c, 3c). Vague tonal lineaments in Holocene alluvium, a broad trough, and east-facing scarp in late Pleistocene alluvium delineate the northern segment of the Inglewood fault zone (figure 3c). North of locality 14 (figure 3c), the fault mapped by Poland and others (1959) could not be verified.

FAULT A

The west-northwest-trending fault near the base of the northern Baldwin Hills mapped by Weber and others (1982) (figure 2b) was generally verified by this writer, although differences in detail exist (figure 3b). The fault generally is moderately well-defined and is characterized by predominantly vertical displacement. A moderately well-defined scarp in an older alluvial fan (Holocene?) indicates possible Holocene activity along the fault (locality 15, figure 3b). Associated geomorphic evidence suggesting recent faulting includes faceted spurs, possible closed depressions, and a trough at the base of a northeast-facing scarp (figure 3b).

FAULT B

The west-northwest-trending fault mapped by Castle (1960) was only partly verified by this writer (figures 2b, 3b). A broad, linear trough in Pleistocene deposits is only moderately defined and geomorphic features along the southeastern projection of this fault were not observed by this writer (figures 2b. 3b).

SEISMICITY

Seismicity in the study area is depicted in figure 6. A and B quality epicenter locations by California Institute of Technology for the period 1932 to 1984 indicate that no well-defined zone of seismicity can be associated with specific segments of the Newport-Inglewood fault zone (figure 6). Several moderate magnitude earthquakes have occurred along the Newport-Inglewood fault zone, including the June 1920 M4.9 Inglewood earthquake, located west of the Potrero and Inglewood faults, the October 1933 M5.4 earthquake east of Reservoir Hill, and the June 1944 M4.5 and M4.4 earthquakes near Dominguez Hill. Surface fault rupture associated with these seismic events has not been reported (Barrows, 1974).

CONCLUSIONS

The Newport-Inglewood fault zone is a difficult feature to evaluate in terms of the hazard of surface fault rupture. The conclusions of Harding (1973) assume that the Newport-Inglewood fault zone is characterized by the wrench-tectonic style of deformation. This style of deformation, which Harding considered to be in the early stages of structural development (after Wilcox and others, 1973), is characterized by a complex pattern of generally discontinuous, left-stepping en echelon right-slip faults and associated anticlinal folding. Slip-rate calculations of 0.5 m/yr by Woodward-Clyde Consultants (WCC) (1979) further suggest that the surface expression of traces of the Newport-Inglewood fault zone is probably subtle. However, it is not certain how the late Quaternary slip-rate relates to the late Cenozoic slip-rate calculated by WCC (1979). If the slip-rate has remained relatively constant from late Miocene through late Quaternary time, one should anticipate that the geomorphic expression of individual strands along the Newport-Inglewood fault zone would be only moderately well-defined at best. In addition, the soft, easily-erodable Quaternary rocks and alluvium along the fault zone would not allow the preservation of ephemeral geomorphic features that develop along strike-slip faults.

RESERVOIR HILL FAULT

The Reservoir Hill fault is a moderately well-defined, right-lateral strike-slip fault (figure 3a). The fault mapped by Poland and others (1956) and zoned for special studies in 1976 was generally verified by this writer, although significant differences in location exist (figures 2a, 3a). Geomorphic evidence suggesting latest Pleistocene to Holocene strike-slip faulting includes a northeast-facing scarp with a possible right-laterally deflected drainage, associated linear trough and tonal lineaments (figure 3a). Site-specific fault investigations have verified the location of the Reservoir Hill fault, but have not been conclusive with respect to recency of faulting (see Johnson and Brown, 1984; Rodine and McNamara, 1984; figure 3a, Table 1). Grading has removed evidence of recent faulting at the Johnson and Brown (1984) location (figures 3a, 4) and considerable controversy exists regarding the identification of lithologic units at the Rodine and McNamara (1984) site (figure 3a, Table 1). However, evidence permissive of Holocene displacement was reported along the southeastern continuation of the Reservoir Hill fault by Bryant (1985) (see also Davis, 1981).

NORTHEAST FLANK FAULT

The Northeast Flank fault is only moderately defined by a northeast-facing scarp in late Pleistocene deposits (figure 3a). The fault mapped by Poland and others (1956) and zoned for special studies in 1976 was mostly verified by this writer, although the southeastern extent of the fault mapped by Poland and others was not verified (figures 2a, 3a). Geomorphic evidence of recent faulting, with the exception of a possible right-laterally deflected drainage, was not observed by this writer, although oil field grading had extensively modified the area of the Northeast Flank fault in the early 1920's.

PICKLER FAULT

The Pickler fault was inferred from oil field data and zoned for special studies in 1976, based on mapping by Poland and others (1956) (figure 2a). This fault generally is not well-defined, partly due to oil field grading. This writer did not verify the Pickler fault mapped by Poland and others (1956).

CHERRY HILL FAULT

The Cherry Hill fault is a moderately well-defined, right-lateral strike-slip fault. The fault mapped by Poland and others (1956) and zoned for special studies in 1976 was mostly verified by this writer (figures 2a, 3a). Geomorphic evidence of latest Pleistocene to Holocene strike-slip displacement includes a moderately well-defined, linear southwest-facing scarp in late Pleistocene deposits, a right-laterally deflected drainage, closed depression(?), and associated tonal lineaments (figure 3a). The northwest continuation of the Cherry Hill fault through Dominguez gap is suggested by a wide, northwest-trending zone of vague tonal lineaments in Holocene alluvium (figure 3a). Site-specific investigations along the Cherry Hill fault are generally inconclusive with respect to recent faulting. However, significant deformation of late Pleistocene deposits is indicated, and permissive evidence of recent faulting can be interpreted locally from very generalized trench logs (Scullin, 1979a; Scullin, 1979c; and Cousineau, 1983) (figure 3a, Table 1).

AVALON-COMPTON FAULT

The Avalon-Compton fault is a northwest-trending, right-lateral strike-slip fault with a minor component of down-to-the-southwest vertical displacement (figure 3b; Ruff and Hannan, 1984). The inferred fault mapped by Poland and others (1959) and zoned for special studies in 1976 generally was not verified by this writer (figures 2b, 3b). Associated geomorphic features suggesting Holocene strike-slip displacement include right-laterally deflected drainages, closed depressions(?), linear troughs, and associated tonal lineaments (figure 3b). A site-specific investigation by Ruff and Hannan (1984) verified this writer's location of the Avalon-Compton fault, but prior grading had removed any Holocene soils (figure 3b, Table 1).

FAULTS IN ROSECRANS HILLS

Several short, left-stepping features in the Rosecrans Hills were observed by this writer northwest of the Avalon-Compton fault (figure 3b). These inferred faults are moderately defined and may be formed by erosion along faults or joints in late Pleistocene deposits rather than recent faulting. However, the left-stepping en echelon pattern is consistent with recent strike-slip faulting observed along the Newport-Inglewood fault zone.

POTRERO FAULT

The Potrero fault is a moderately well-defined strike-slip fault with a component of down-to-the-southwest vertical displacement (figure 3b). The fault mapped by Poland and others (1959) and zoned for special studies in 1976 was partly verified by this writer although differences in detail exist (figures 2b, 3b). The Potrero fault is delineated by a partly dissected, southwest-facing scarp in late Pleistocene deposits. Associated geomorphic features permissive of latest Pleistocene to Holocene strike-slip faulting include right-laterally deflected and vertically offset drainages, closed depressions, a linear trough, and associated tonal lineaments (figure 3b). The short, northeast-trending cross-faults mapped by Poland and others (1959) and Castle (1960) are not well defined and were not verified by this writer, based on air photo interpretation (figures 2b, 3b). The Townsite fault mapped by Poland and others (1959) was not verified by this writer, except at locality 14 (figure 3b).

INGLEWOOD FAULT ZONE

The Inglewood fault zone is a relatively complex zone of moderately defined strike-slip and vertical faults (figures 3b, 3c). The complex fault zone mapped by Poland and others (1959) and Castle (1960) was only partly verified by this writer, based on air photo interpretation (figures 2b, 2c, 3b, 3c). Recently active segments of the Inglewood fault zone form both a left- and right-stepping pattern, perhaps indicating complexities related to a more significant vertical component of displacement, based on the more northly trend of the fault zone. Geomorphic features indicating recent faulting along the Inglewood fault zone include southwest-facing scarps in late Pleistocene deposits, right-laterally deflected drainages, faceted spurs, and a scarp and tonal lineaments in Holocene alluvium on the south side of Ballona Creek (figures 3b, 3c). The northwest continuation of the Inglewood fault mapped by Poland and others (1959) and zoned for special studies in 1976 was only partly verified by this writer and is generally not well-defined (figures 2c, 3c). Two site-specific fault investigations by Brown (1980) and Byer (1982) reported no evidence of faulting in late Pleistocene Lakewood Formation (figure 2c, Table 1).

Additional faults in the Baldwin Hills mapped by Castle (1960) and zoned for special studies in 1976 are not well-defined and were not verified by this writer (figures 2b, 2c, 3b, 3c).

Historic creep along north- and northeast-trending faults and fault-like features have been mapped by Castle and Yerkes (1969) and Castle and Yerkes (1976) (figures 2c, 2d). These minor surface rupture events, most noticeably linked to the failure of the Baldwin Hills dam in December 1963 (CDWR, 1964), are thought to be caused primarily by subsidence related to fluid withdrawal (Castle and Yerkes, 1976).

FAULT A

Fault A is a west-northwest-trending fault along the northern front of the Baldwin Hills and is characterized by down-to-the-north vertical displacement (figures 2b, 3b). This fault was zoned for Special Studies in 1976, based on mapping by Castle (1960). Poland and others (1959) (figure 2d) and Weber and others (1982) (figure 2b) also mapped this fault. Weber and others inferred that Holocene alluvium was offset along Fault A (figure 2b). An offset old alluvial fan (early Holocene?) mapped by this writer, based on air photo interpretation (locality 15, figure 3b), partly corresponds with the fault mapped by Weber and others (1982) (figure 2b). Fault A is moderately defined, but may be, in part, modified by erosion.

FAULT B

Fault B was mapped by Castle (1960) as an inferred fault, based on the anomalous location of Pleistocene sands in Ballona gap and lithologic discontinuities based on water-well data. This inferred fault was projected to the southeast as concealed and was zoned for special studies in 1976 (figure 2b). The inferred fault is generally not well-defined and was only partly verified in Pleistocene deposits by this writer (figure 3b). A site-specific investigation by D. Moran did not expose evidence of faulting in Holocene and late Pleistocene alluvium along the southeastern end of this inferred fault (D. Moran, p.c., October 1985).

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

RESERVOIR HILL FAULT

Zone for special studies traces of the Reservoir Hill fault depicted in figure 7a. Principal references cited should be this FER and Johnson and Brown (1984).

NORTHEAST FLANK FAULT

Zone for special studies those traces of the Northeast Flank fault depicted in figure 7a. Principal references cited should be this FER and Poland and others (1956).

PICKLER FAULT

Zone for special studies only those traces that are well-defined as depicted in figure 7a. Delete traces of the Pickler fault originally zoned for special studies in 1976.

CHERRY HILL FAULT

Zone for special studies traces of the Cherry Hill fault depicted in figure 7a. Principal references cited should be Poland and others (1956) and this FER.

AVALON-COMPTON FAULT

Zone for special studies traces of the Avalon-Compton fault depicted in figures 7b and 7c. Principal references cited should be this FER and Ruff and Hannan (1984).

FAULTS IN ROSECRANS HILLS

Zone for special studies traces of faults in the Rosecrans Hills depicted in figure 7c. Principal reference cited should be this FER.

POTRERO FAULT

Zone for special studies traces of the Potrero fault depicted in figure 7c. Principal reference cited should be this FER.

INGLEWOOD FAULT ZONE

Zone for special studies traces of the Inglewood fault zone depicted in figures 7c, 7d, and 7e. Include those features along which historic surface rupture has occurred. Principal references cited should be Castle and Yerkes (1976) and this FER.

FAULT A

Zone for special studies traces of Fault A depicted in figure 7c. Principal reference cited should be this FER.

FAULT B

Delete traces of Fault B. This fault is neither sufficiently active nor well-defined.

Air photos checked and report reviewed. I agree with recommendations. Earl W. Hart 11/22/85

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TABLE 1 - Summary of Selected Consulting Reports
Filed with DMG

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Allen (May 1977) AP-1639	Cherry Hill fault	No	N/A	Two trenches (240') excavated to depth of 8' to 9'. No evidence of faulting reported in late Pleistocene terrace deposits. A slight monoclinal warp in late Pleistocene deposits is suggested in trench B, indicating down-to-SW direction. However, trench logs are extremely generalized.
Brown, Van Beveren and Kirkgard (Nov. 1980) AE--80322 AP-1601	Cherry Hill fault	No	N/A	Two trenches totaling 164' excavated to depths of about 10'. No evidence of faulting reported in trenches. Faulting in late Pleistocene deposits is weakly suggested in trench 2 at Sta. 95 where a down-to-the-SW flexure is suggested. However, this is weak evidence for faulting.
Cousineau (July 1978) 140-078 AP-1575	Cherry Hill fault	No	N/A	One 170' long trench excavated. Artificial fill from 3' to 6' thick encountered. Trench averaged 9' to 10' deep. No faulting reported.
Cousineau (April 1983) 1094-043 AP-1540	Cherry Hill fault	No	N/A	One trench (115') excavated to depth of 10'. No evidence of faulting reported. However, contacts of units parallel ground surface, which has an apparent slope of 12^{o}-14^{o} to the south. Units identified were pre-Holocene terrace deposits. Some amount of tectonic deformation is indicated by apparent dip of deposits.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Earnest & Nevin(June 1978) 584G AP-1576	Cherry Hill fault	No	N/A	Two trenches totaling 295', average depth 9' (locally 20'). No evidence of faulting reported in late Pleistocene terrace deposits. Trench T-1 apparently crossed mapped trace of fault. Consultant stated that bedding plane attitudes were not discernible in trenches. Thus, deformation cannot be ruled out based on this information. A petroliferous sand deposit severely caved and perhaps obscured evidence of faulting. This sand unit pinches out to the SW, and is perhaps offset.
Evans (June 1977) 77-71 AP-589	Cherry Hill fault	No	N/A	Two trenches totaling 90' excavated to depths of 8' to 12'. No evidence of faulting reported. Trenches very close to mapped trace of southern end of Cherry Hill fault. Based on my interpretation of photos, fault does not extend this far southeast.
Johnson and Brown (Oct. 1975) E-75197 AP-451	Reservoir Hill fault	No	N/A	Two trenches totaling 350' excavated to depths of 7' to 12'. No evidence of faulting found. Trenches crossed mapped trace of fault. However, it is probable that fault is located west of site. Thick fill encountered in most of exposures - no indication of structure and bedding provided in trench logs.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Johnson and Brown (March 1984) AE-84016 AP-1681	Reservoir Hill fault	Yes	late Pleisto-cene	Evidence of major faulting located in trenches 1, 3, 5. San Pedro Fm. on west faulted against Lakewood Fm. on east. Surface had been graded, so young deposits overlying Lakewood Fm. have been removed. Consultant stated that youngest deposits may be 15,000 yr. old. Zone is as wide as 60' in T-1. Setbacks were recommended. Fault was located as much as 180' SW of mapped trace of fault (1976 SSZ map). Consultant concluded fault was normal, although principal fault oriented from N55°W 87°SW to N36°W 86°NE. Subsidary or branch fault is SW-dipping reverse fault. Magnitude of offset could not be determined. It is probable that fault is significant r.l. strike-slip fault with component of down-to-east normal faulting. Evidence of liquefaction reported, including sand dikes and sand boils.
Merrill (July 1976) 63427 AP-262	Cherry Hill fault	No	N/A	1 trench 5' deep excavated - no fault reported in trench- trench much too shallow to account for any faulting of late Holocene floodplain deposits.
Merrill (July 1976) 63480 AP-1643	Cherry Hill fault	No	N/A	Two trenches excavated, no evidence of faulting reported (Logs not in report).

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Merrill (Aug. 1977) 74021 AP-707	Reservoir Hill fault	No	N/A	One trench 590' long about 10' deep excavated. Consultant observed fault in natural exposure (?) where terrace deposits(?) are faulted (fault att. N33°W76°NE). Fault trace projected across trench on location map, but trench log does not show evidence of fault. Consultant stated that soil was not offset by fault, but this has not been documented in report.
Merrill (April 1978) 84444 AP-1579	Cherry Hill fault	No	N/A	Two trenches excavated. No logs provided in report. Consultant stated that no faults were observed.
Rodine & McNamara (1985) C-606	Reservoir Hill fault	Yes	latest Pleisto-cene	Fault located and trends diagonally across property. Zone of faults located. Trend of principal fault N38°W to N40°W, with vertical dip. Fault offsets latest Pleistocene Lakewood Fm., but controversy exists as to youngest unit not faulted. Consultant reported that uppermost Lakewood Fm. is not offset by fault, concluded that fault is not active and recommended that no building setback be established. City of Long Beach geologist, D.D. Clarke observed excavations and concluded that fault offsets all natural units (latest Pleistocene), and contends that youngest unit not faulted is artificial fill. Logs of exploration trenches do not support consultants conclusion that latest Pleistocene deposits are not offset. Thus, fault probably offsets all natural deposits, but recency was not established due to prior grading.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Scullin (July 1976) G76160 AP-276	Cherry Hill fault	No	N/A	One 118'-long trench excavated to 11' depth. Artificial fill ranged from 3' to 11' thick.
Scullin (Feb. 1977) 77117 AP-388	Cherry Hill fault	No	N/A	Trench may have crossed mapped trace of fault, but location "map" is only an approximate sketch. Trench was 100' long and locally, 12' deep. Thick articicial fill (up to 10' thick) reported. Log of trench generally inadequate to document evidence for or against presence of subtle features that may indicate faulting.
Scullin (Jan. 1978) 78102 AP-644	Reservoir Hill fault	No	N/A	One trench 73' long excavated to depth of 7'. No faulting reported in Pleistocene deposits. Trench apparently did not cross mapped trace of Reservoir Hill fault.
Scullin (Jan. 1979) 79106 AP-1572	Cherry Hill fault	Yes	latest Pleistocene to Holocene (?)	Six tenches excavated to depths averaging 10' deep. Faults reported in trenches T-2 and T-6 offset unit identified as Palos Verdes sand (Qt_3) Overlying terrace deposit (Qt_1) reportedly not offset. However, old erosion surface identified between Qt_3 and Qt_1 in T-2 is deformed, suggesting tectonic deformation. Beds in Qt_3 dip 25°SW NE of fault and 45°SW SW of fault. Schlemon in an investigation just south of the site, identified a 10,000-20,000 yr. paleosol that is probably Qt_1. Thus, tectonic deformation may be latest Pleistocene to early Holocene.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
LONG BEACH QUADRANGLE				
Scullin (March 1979) 79110 AP-1578	Northeast Flank fault	No	N/A	One trench (100') excavated to depth of 6' to 9'. No evidence of faulting reported.
Scullin (April 1979) 79123 AP-1697	Cherry Hill fault	Yes	latest Pleistocene	Two trenches excavated to depths to 9'. Trenches located east of mapped trace of fault, in upthrown side. Consultant reported no evidence of recent faulting, specifically that minor faults didn't cut younger terrace deposits. However, no younger terrace deposits (Qt_1) where across faults. The most significant aspect of trench exposures was the deformation of the late Pleistocene terrace deposits. At the northeast end of trench beds dipped 15°SW & near the SW end of the trench the dip steepened to 45°SW, which was nearly coincident with the scarp-slope. This structure strongly indicates significant deformation of a up-on-the-east reverse oblique fault. The small shears reported in the two trenches probably related to deformation on up-throw side of reverse fault.
Scullin (Dec. 1982) 82128 AP-1613	Cherry Hill fault	No	N/A	Two trenches excavated to 7' to 9'. No evidence of faulting reported. Thick fill to 6' encountered.
Scullin and Simon (March 1985) 2279-01 C-605	Reservoir Hill	possibly	possibly historic	Clay and sand-filled fractures reported in pre-1933 artificial fill. Fractures align with regional trend of Reservoir Hill fault and have N43°W 80°-90°SW altitude. In deep trench excavations, it was reported that fractures are continuous, linear features for a distance of at least 30 meters. Trench T-5, deepened in order to expose natural materials,

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
Scullin and Simon (contd)				apparently did not have evidence of faulting in bedrock. However, excavation caved in natural deposits where faulting was anticipated, thus precluding detailed examination of exposures. Consultant concluded that fractures in pre-1933 fill were formed either by seismic shaking associated with 1933 Long Beach earthquake or differential settlement cracks; not surface fault rupture features.
INGLEWOOD QUADRANGLE				
Byers (March 1979) KB4363-S AP-983	NE-trending cross fault-Inglewood fault zone	No	N/A	One trench (160', 7' deep) excavated, no evidence of faulting reported.
Cousineau (Oct. 1980) 670-100 AP-1282	Inglewood fault	No	N/A	Two trenches totaling 407' (6' to 11' deep). No evidence of faulting reported. Trenches excavated just west of inferred fault trace.
Cousineau (Jan. 1982) 915-012 AP-1454	Inglewood fault	No	N/A	One trench (150' long, 8' deep) excavated just west of inferred fault trace. No evidence of faulting reported.
Cousineau (Feb. 1982) 928-022 AP-1433	"Cemetery" fault (NE-trending cross fault)	No	N/A	One trench (60' long, 8' deep) excavated just north of inferred fault. No evidence of faulting reported.
Harter and Kirkgard (Feb. 1985) 3191-52 AP-1769	Inglewood fault	No	N/A	One trench (130' long, 6' deep) excavated. No evidence of faulting reported. Deposits are late Pleistocene terrace deposits with moderately developed pedogenic B-soil horizon.
Howe and Payne (May 1984) S-0853-E AP-1719	Inglewood fault	No	N/A	One trench (120' long, 5' to 6' deep) excavated; no evidence of faulting reported. Trench exposed late Pleistocene terrace deposits (Lakewood Fm.). Well-developed argillic B-soil horizon developed on terrace

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
INGLEWOOD QUADRANGLE				
Howe and Payne (contd)				deposits; clay skins on ped. surfaces. Consultant estimated that terrace deposits greater than 10,000 yr.old, perhaps as old as 100,000 ybp. Also, it was estimated that B horizon was thicker than depth of trench.
Hu and Cousineau (July 1980) HA1070-4 AP-1223	Townsite fault	No	N/A	One trench 67' long, 7' deep excavated just west of inferred fault-No evidence of faulting reported.
Larson & Yoakum (Jan. 1981) 966-VN AP-1283	Potrero fault; NE-trending cross fault	No	N/A	Trenches excavated to 12' deep, no evidence of faulting reported. Trend STP-1 crossed inferred trace of Potrero fault. No apparent offsets-two features described as "staining" had measurable trends-N19°W 85°E and N69°E 89°N. These features occurred at topographic base of west-facing slope-additional "stains"-fracture with iron and manganese staining, located to the west with trends from N18°W to N8°E, all are near vertical. No bedding att. mentioned for terrace deposits-logs generalized. No evidence of faulting reported for NE-trending cross-fault.
Lass & Eagen (Nov. 1978) 178-122 AP-874	NE-trending cross fault-Inglewood fault zone	No	N/A	About 775' of trenching excavated to depths from 5' to (locally) 10' deep. No evidence of faulting reported. Air photo interpretation by consultants stated no geomorphic evidence of recent fault west of Inglewood fault.
Lockwood & Singh (Oct. 1978) BZ5-72 AP-888	NNE-trending fault in Baldwin Hills	No	N/A	One trench excavated, no evidence of faulting reported. No trench log included in report.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
INGLEWOOD QUADRANGLE				
Merrill (Feb. 1977) AP-398	NE-trending "earth crack"	Yes	Holocene(?)	Minor faulting re-activated by oil field operations produced surface deformation east and west of site. Minor faulting reported in trench apparently doesn't cut soil (graphic log not included in report). Soil is probably late Holocene colluvium.
Merrill (Sept. 1979) 95003 AP-1028	Avalon-Compton	No	N/A	One trench 600' long excavated to depths of 5' to 14' deep. No evidence of faulting reported in late Pleistocene alluvium. However, near-vertical contact between gravel on west and sand on east at Sta. 3 + 60 suggests faulting. Site has been extensively altered by grading.
Munson (March 1981) AP-1328	Inglewood fault	No	N/A	One 95' long, 6' to 7' deep trench excavated across inferred fault trace. No evidence of faulting reported. Soil-filled fissures in late Pleistocene Lakewood Fm. incorporated overlying soil-some fractures extended up into soil horizon (thick B?). Consultant concluded fractures were relict dessication cracks-slickensided surfaces reported on the fracture surface, but no indication of orientation of slickensides.
Munson (Feb. 1983) AP-1536	Inglewood fault	Yes	latest Pleistocene	Minor fault offsets late Pleistocene Lakewood Fm. (flt.att. N-S, 80°W)-magnitude of offset not known-overlying soil doesn't appear to be offset.
Rinne and Johnson (May 1980) 10711-001-02 AP-1159	Short, NW-trending fault along E. side of Baldwin Hills	No	N/A	One 250' long trench excavated to depth of about 10'. No evidence of faulting reported. Geophysical survey (seismic reflection) by Gasch & Assoc. reported no evidence of near-surface faulting.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
INGLEWOOD QUADRANGLE				
Ruff and Hannan (April 1984) 83-02218-02 AP-1814	Avalon-Compton fault	Yes	late Pleistocene	Principal trace of Avalon-Compton fault exposed in two trenches. Site formerly had been dump site, so natural soils have been disturbed or removed. Principal fault att. N20°W 90°-small drag folds in beds indicate down-to-the-west component of vertical offset which is consistent with the west-facing scarp associated with the fault. Slickensides along westernmost fault indicate horizontal and oblique slip. Fault zone exposed in trench T-5 is about 55' wide. Deposits offset are late Pleistocene Lakewood Fm. Holocene displacement was not demonstrated due to removal of overlying soils, but also cannot be ruled out. Major stratigraphic discontinuity across principal fault trace reported in both trench T-5 and bore-hole data. Setback recommended.
Schrenk & Howser (May 1978) AP-777	NE-trending cross fault-Inglewood fault zone	Yes	Pleistocene	Minor faults offseting early Pleistocene San Pedro Fm. Offsets ranged from 1/2" to 6", overlying soil removed by grading. Although no evidence for recency observed, building setback of 10' recommended.
Scullin (Oct. 1981) 81154 AP-1400	Inglewood fault	No	N/A	One trench (125' long, 12' to 14' deep) excavated across inferred trace. No evidence of faulting reported in late Pleistocene Lakewood Fm.
Shmerling & Robinson (Jan. 1978) 5702 AP-688	NE-trending cross fault-Inglewood fault zone	No	N/A	Three trenches totaling 100 feet excavated to depths of 6' to 13'. No evidence of faulting reported in alluvial deposits.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
INGLEWOOD QUADRANGLE				
Tucker & Tousa (Sept. 1983) 2127-83 AP-1619	Potrero fault	No	N/A	Trenches excavated to 6' to 8' deep in late Pleistocene Lakewood Fm. No evidence of faulting reported. However, contacts between units of Lakewood Fm. nearly parallel SW-facing slope, indicating that they may be tectonically deformed. Consultant stated that fault, based on geomorphic evidence, is located 200' to 240' west of the site.
HOLLYWOOD QUADRANGLE				
Clements (Jan. 1979) AP-918	NW-trending fault along base of Baldwin Hills	No	N/A	Two trenches excavated from 5' to 8' deep. No evidence of faulting reported. Bedding att. N20°W 20°NE in Plio-Pleistocene shale and sandstone.
Clements (May 1980) AP-1206	NE and NW-trending "earth cracks" in Baldwin Hills	Yes	Historic	Cracks in Palos Verdes sand extend into artificial fill-cracks have trends ranging from N25°E to N20°W-cracks related to oil field subsidence. Cracks do not seem to displace bedding, but trench log is highly generalized.
Lung (June 1977) 77125-1 AP-502	NW-trending feature NE of Baldwin Hills	No	N/A	One trench (193') excavated to 5' deep in Holocene alluvium. No evidence of faulting reported.
Merrill (April 1978) 84392 AP-812	NW-trending fault along base of Baldwin Hills	No	N/A	Four trenches excavated, no evidence of faulting reported.
Merrill (May 1978) 84393 AP-844	NNE-trending fault in Baldwin Hills	Yes	Historic (?)	Minor fault NNE-trending with 70°W dip offsets Inglewood Fm. approx. 1" (down to west) and offsets Holocene soil (colluvium?). This feature is probably related to oil field subsidence.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
HOLLYWOOD QUADRANGLE (contd)				
Munson (Jan. 1981) AP-1262	Short NW-trending fault	Yes	pre-Holocene	Several shears in Plio-Pleistocene(?) sedimentary rocks-overlying colluvium not offset Consultant considered faults normal with from 0.5' to 2' of displacement.
Robinson (Dec. 1978) 0185 AP-940	NW-trending fault in northeastern Baldwin Hills	No	N/A	Three trenches excavated in Pleistocene San Pedro Fm.-no evidence of faulting reported.
Tucker (Feb. 1979) 223-79 AP-977	NW-trending fault along base of Baldwin Hills	No	N/A	Two trenches (130') excavated from 3' to 5' deep in Pleistocene San Pedro Fm. No evidence of faulting reported. Bedding in San Pedro Fm. near horizontal.
BEVERLY HILLS QUADRANGLE				
Brown (May 1980) ADE-80099 AP-1229	Beverly Hills segment Inglewood fault	No	N/A	One 100' long, 10' deep trench excavated across inferred fault trace. Apparent NE-facing scarp (break in slope) underlain by continuous deposits identified by consultant as late Pleistocene Lakewood Fm. No evidence of faulting reported.
Byer (Feb. 1982) KB6656-S AP-1631	Beverly Hills segment Inglewood fault	No	N/A	Two trenches totaling 136' to depths from 7' to 11'. Trenches excavated across NE-facing scarp. No evidence of faulting reported. Alluvium (colluvium?) in trench exposure deposited across escarpment. However, trenches not deep enough to adequately expose Lakewood Fm. at scarp. Thus, not clearly established whether scarp erosional or due to faulting.

Consulting Report Project No. DMG file No.	Fault Investigated	Fault Located ?	Recency Established	Remarks
BEVERLY HILLS QUADRANGLE (contd)				
Eagen (Aug. 1975) 475-28 AP-196	Projected trend of unnamed fault in Baldwin Hills	No	N/A	Five trenches excavated. No faults reported in deposits assumed to be Holocene fluvial deposits.
Fisher (March 1981) 81001-2 AP-1286	Beverly Hills segment Inglewood fault	No	N/A	One test pit (14') excavated to 14' deep in Holocene(?) alluvium. Trench excavated about 50'-100' E. of mapped (concealed) trace. No evidence of faulting reported, although exposure not adequate to rule out faulting near site.
Shubeck and Schrenk (March 1984) AP-1678	Beverly Hills segment Inglewood fault	No	N/A	One 129' long trench excavated to 10' deep. No evidence of faulting reported in Holocene alluvium.

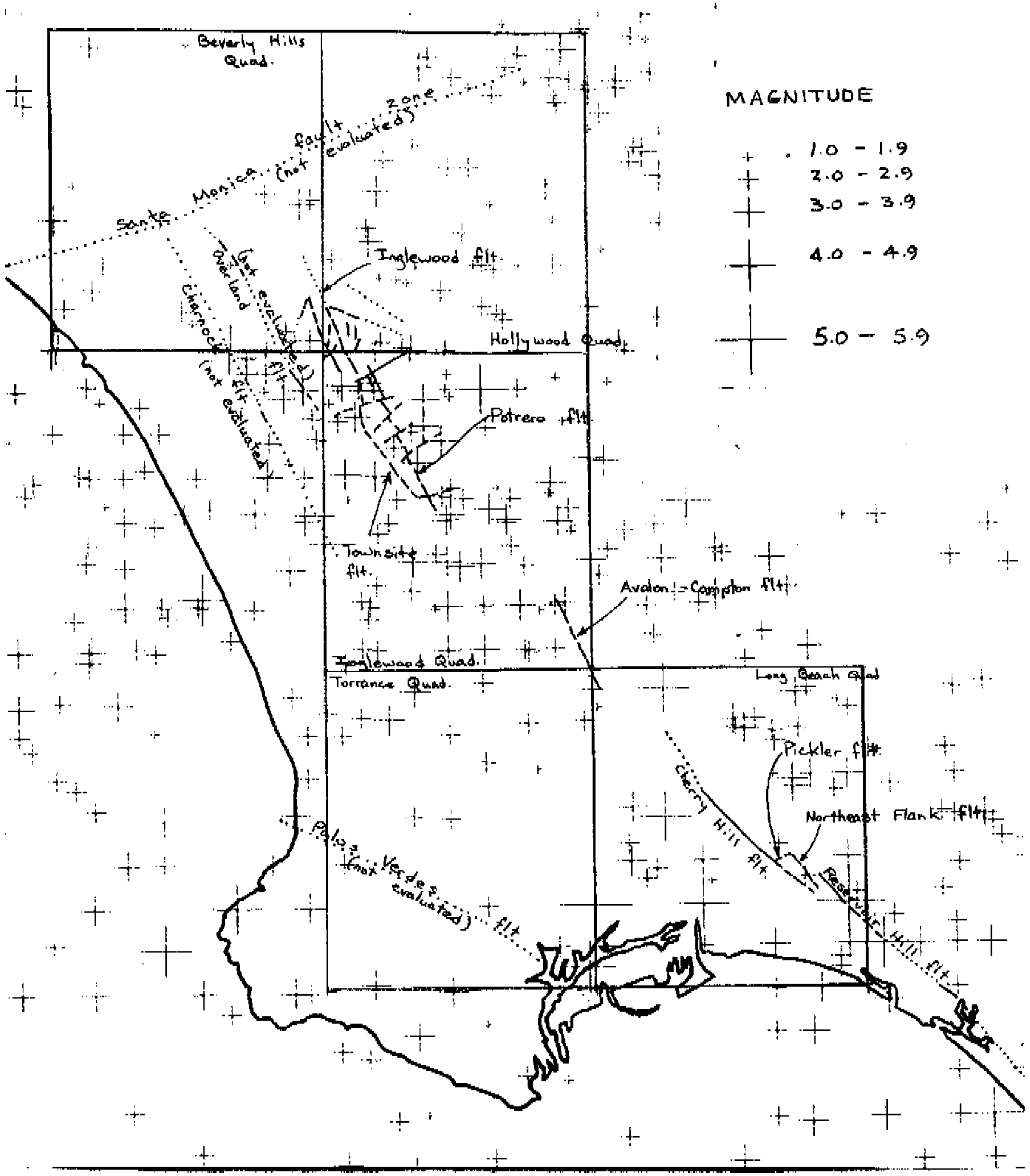

Figure 6 (to FER-173). Seismicity (A and B quality) in the study area for the period 1932 to 1984, based on locations from California Institute of Technology. Faults are from Jennings (1962) and Jennings and Strand (1969).

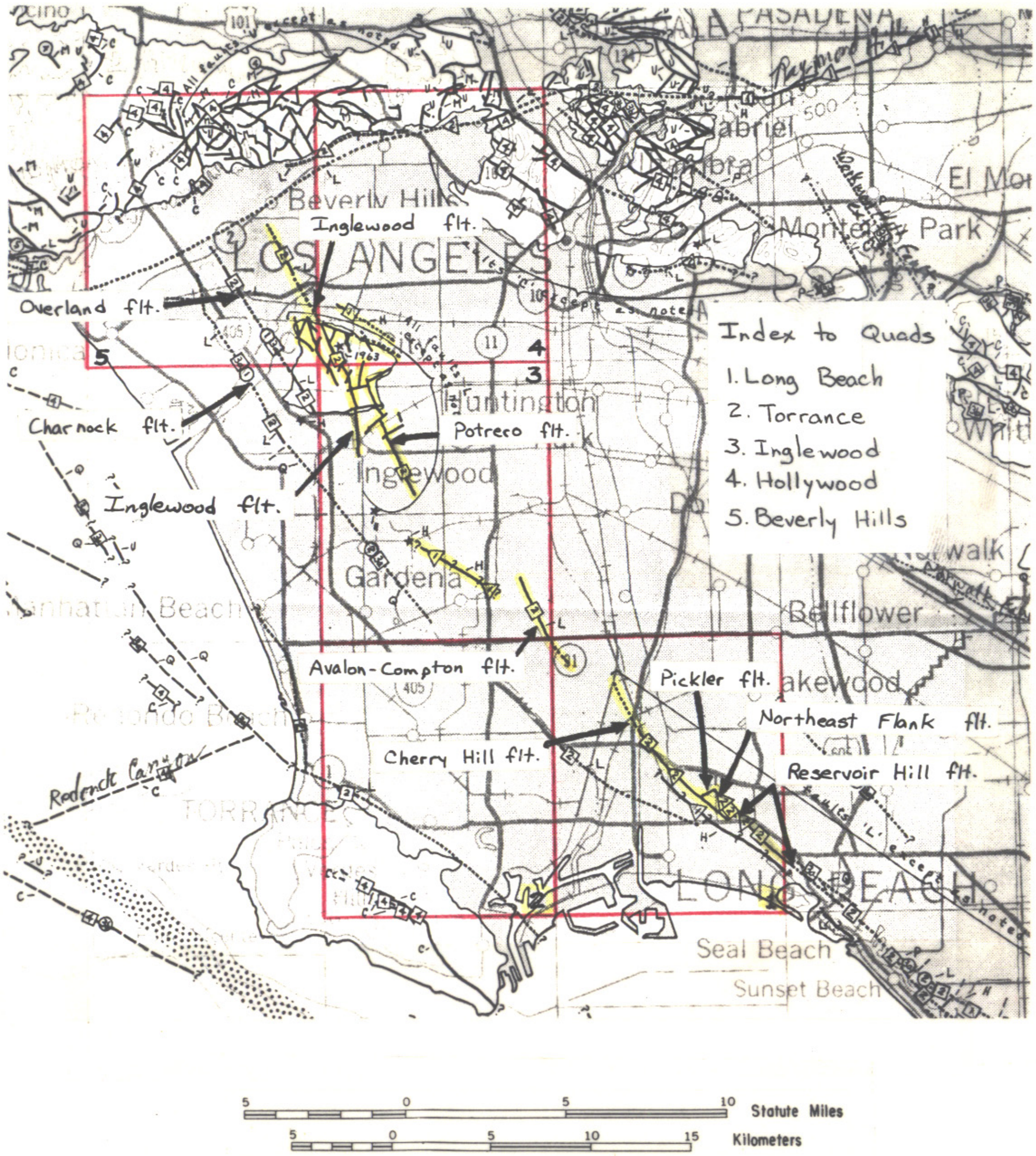

Figure 1 (to FER-173). Location of faults in the Los Angeles County study area. Faults evaluated in this FER are highlighted in yellow. Map from Ziony and others (1974).

ATTACHMENT F

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Puente Hills Blind-Thrust System, Los Angeles, California

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Abstract We describe the three-dimensional geometry and Quaternary slip history of the Puente Hills blind-thrust system (PHT) using seismic reflection profiles, petroleum well data, and precisely located seismicity. The PHT generated the 1987 Whittier Narrows (moment magnitude [M_w] 6.0) earthquake and extends for more than 40 km along strike beneath the northern Los Angeles basin. The PHT comprises three, north-dipping ramp segments that are overlain by contractional fault-related folds. Based on an analysis of these folds, we produce Quaternary slip profiles along each ramp segment. The fault geometry and slip patterns indicate that segments of the PHT are related by soft-linkage boundaries, where the fault ramps are en echelon and displacements are gradually transferred from one segment to the next. Average Quaternary slip rates on the ramp segments range from 0.44 to 1.7 mm/yr, with preferred rates between 0.62 and 1.28 mm/yr. Using empirical relations among rupture area, magnitude, and coseismic displacement, we estimate the magnitude and frequency of single (M_w 6.5–6.6) and multisegment (M_w 7.1) rupture scenarios for the PHT.

Introduction

The Los Angeles basin lies along the southern California coast at the junction of the Transverse and Peninsular Ranges. The basin is currently being deformed by several blind-thrust and strike-slip faults that have generated historic, moderate-size earthquakes (Hauksson, 1990; Dolan *et al.*, 1995). Geodetic studies suggest that the northern basin is shortening at a rate of 4.4–5 mm/yr in a north–south to northeast–southwest direction (Walls *et al.*, 1998; Argus *et al.*, 1999; Bawden *et al.*, 2001). Part of this shortening is accommodated on recognized fault systems, and two competing models have been proposed to explain which faults account for the remainder. Walls *et al.* (1998) suggested that the remaining shortening is accommodated by higher rates of slip on conjugate strike-slip systems in the northern basin. Motion on these faults produces north–south shortening by lateral crustal extrusion. In contrast, Argus *et al.* (1999) and Bawden *et al.* (2001) proposed that the shortening is accommodated primarily by activity on thrust and reverse faults. In this article, we document an active blind-thrust system in the northern Los Angeles basin, termed the Puente Hills blind thrust (PHT), that accommodates a component of the unresolved basin shortening and poses substantial earthquake hazards to metropolitan Los Angeles.

The PHT extends for more than 40 km along strike in the northern Los Angeles basin from downtown Los Angeles east to Brea in northern Orange County (Fig. 1). The fault consists of at least three distinct geometric segments, termed Los Angeles, Santa Fe Springs, and Coyote Hills, from west to east. Shaw and Shearer (1999) defined the central portion of the PHT with seismic reflection profiles and petroleum well data. Using precisely relocated seismicity, these authors proposed that the Santa Fe Springs segment of the PHT generated the 1987 (M_w 6) Whittier Narrows earthquake. In this article, we define the size and three-dimensional geometry of the PHT using additional seismic reflection data. We describe the systematic behavior of the segments that compose the PHT and consider the geometric and kinematic relations of the PHT to other blind-thrust and strike-slip systems. Finally, we map the distribution of slip on the PHT and discuss the implications of this study for earthquake hazard assessment in metropolitan Los Angeles.

Puente Hills Blind Thrust

Displacements on the PHT contribute to the growth of a series of en echelon anticlines in the northern Los Angeles basin that involve Miocene through Quaternary strata. The easternmost fold forms the Coyote Hills and provides structural closure for the east and west Coyote Hills oil fields (Yerkes, 1972). The central fold has only subtle surface expression and provides structural closure for the Santa Fe Springs oil field (Fig. 1). The westernmost fold is contained within a broad, south-dipping monocline that forms the northern boundary of the Los Angeles basin (Davis *et al.*, 1989; Shaw and Suppe, 1996; Schneider *et al.*, 1996). All of these folds are bounded on their southern margins by narrow forelimbs (Fig. 2). These forelimbs, or kink bands, consist of concordantly folded, south-dipping Pliocene

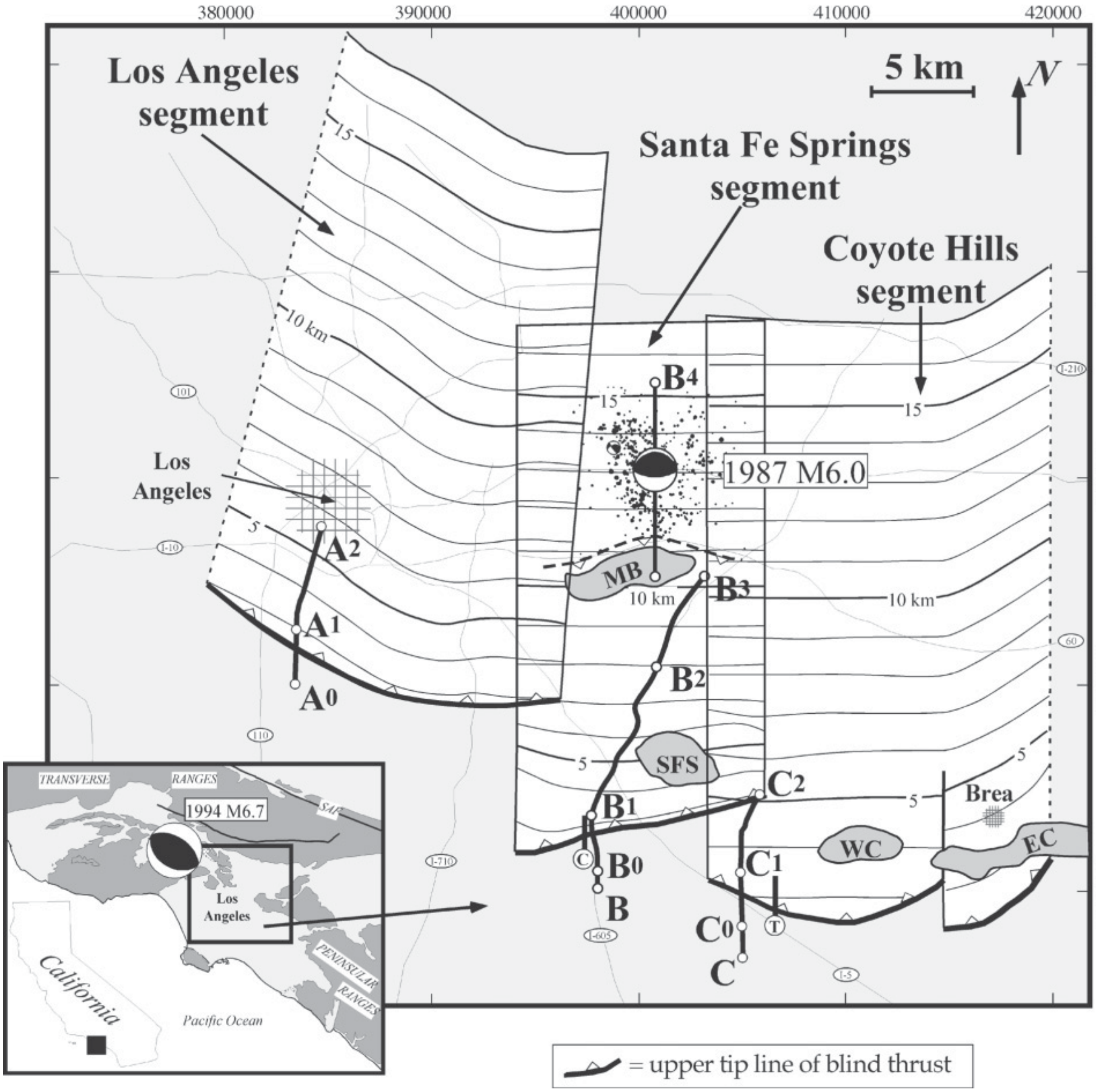

Figure 1. Structure contour map of segments of the Puente Hills blind thrust (PHT) showing the location of the 1987 Whittier Narrows (M_w 6) earthquake sequence (Hauksson and Jones, 1989) as relocated by Shaw and Shearer, (1999). A^0–A^2, B–B^4, and C–C^2 mark the traces of seismic reflection profiles and cross sections shown in Figures 2, 3, 5, 7, and 8. Traces T and C correspond to the high-resolution seismic profiles presented in Figure 4. The inset shows the location of the PHT and 1994 Northridge (M_w 6.7) earthquake. Oil fields: EC, East Coyote; WC, West Coyote; SFS, Santa Fe Springs; MB, Montebello. Major state and interstate highways are shown for reference. Map coordinates are UTM Zone 11, NAD27 datum.

strata. Overlying upper Pleistocene and younger units thin across these folds, suggesting that they were deposited concurrent with fold growth and fault activity (Yerkes, 1972; Myers, 2001). The kink bands generally narrow upward into this upper Pleistocene and younger section, forming growth triangles. These growth structures are diagnostic of fault bend and certain types of tip line or fault propagation folding (Suppe *et al.*, 1992; Shaw and Suppe, 1994; Allmendinger, 1998).

The PHT and overlying folds are imaged in a set of 43 seismic reflection profiles available for this study that were acquired by the petroleum industry along roads, rivers, and utility rights of way in the northern basin. The PHT is expressed directly in 24 of these profiles as a series of north-dipping reflections that extend downward from the base of the forelimb kink bands beneath the cores of the anticlines. Based on velocity functions derived from more than 150 sonic logs and 7000 stacking velocity measurements (Süss

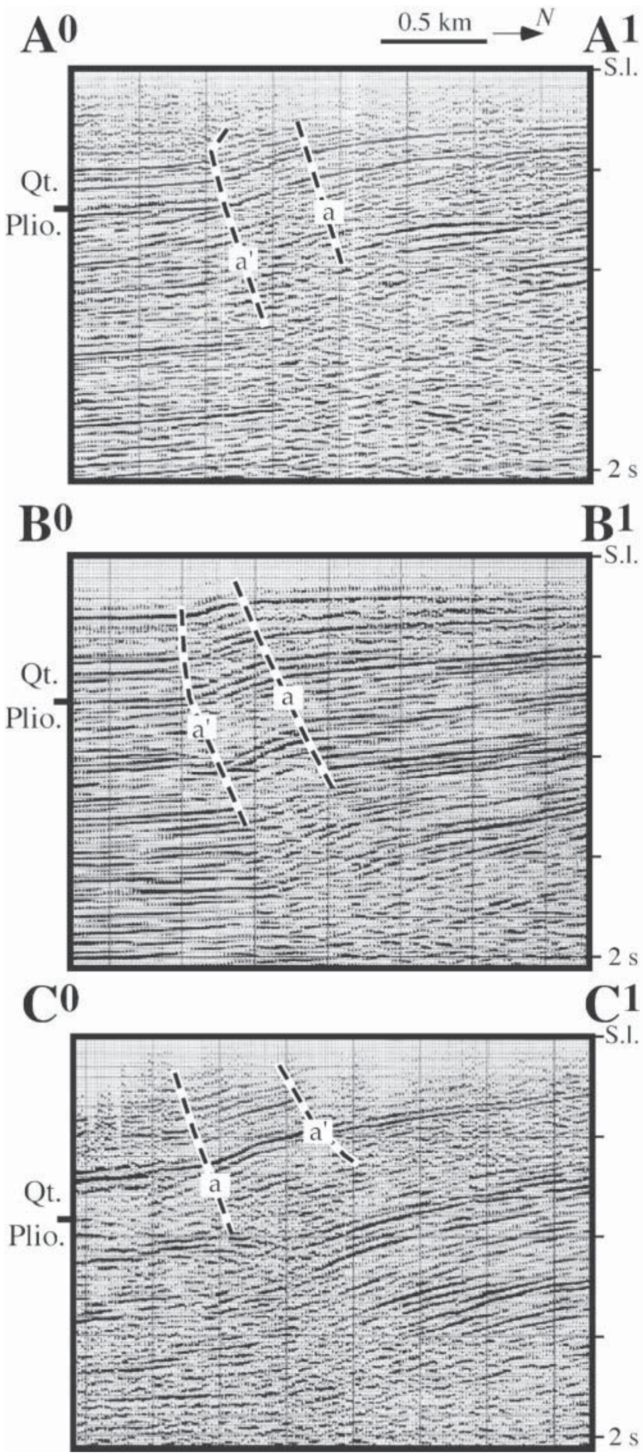

Figure 2. Migrated seismic reflection profiles across the forelimb kink bands (aa′) that mark the southern termination of the Los Angeles (A^0–A^1), Santa Fe Springs (B^0–B^1), and Coyote (C^0–C^1) segments of the Puente Hills blind thrust. The fold limbs are overlain by Quaternary growth strata that thin to the north onto the crests of the structures. Profile traces are shown in Figure 1.

and Shaw, 2002), the seismic data were depth converted revealing that the fault-plane reflections dip to the north at 25° to 30°. A structure contour map based on the fault-plane reflections indicates that the PHT strikes generally east–west, and that it is composed of three distinct geometric segments termed Coyote Hills, Santa Fe Springs, and Los Angeles (Shaw and Shearer, 1999). This en echelon fault pattern mimics the trend of the overlying folds.

Santa Fe Springs Segment

The best-imaged portion of the PHT lies beneath the Santa Fe Springs anticline, where fault-plane reflections extend from about 3- to more than 7 km depth (Fig. 3). The thrust ramp dips to the north at about 25°–29° and terminates upward at the base of the forelimb kink band (aa′) on the southern margin of the fold. To the north of this kink band is located a second, apparently older hanging-wall fold defined by anticlinal axial surface (c) and a steeply southwest-dipping fold limb (Fig. 3). A gently southwest-dipping monoclinal fold also underlies the PHT. This footwall structure has been interpreted to reflect deformation above the lower Elysian Park thrust (Shaw and Suppe, 1996).

In contrast to the shallow, tight kink-band (aa′), the northern hanging-wall fold (c) in the Santa Fe Springs anticline is broad and open (Fig. 3). Thinning of strata across this northern limb suggests that it formed in the Pliocene during an early stage of activity on the PHT. Allmendinger and Shaw (2000) modeled this Pliocene structure as a trishear fault-propagation fold (Erslev, 1991; Allmendinger, 1998) and showed that the fold shape was consistent with the imaged fault geometry. Late Pliocene (uppermost Fernando Fm.) and Quaternary strata overlie but are not involved in this broad fold limb, suggesting that this portion of the structure stopped growing in the late Pliocene. A period of tectonic quiescence is defined by a 500-m-thick section of late Pliocene strata that does not change thickness across the forelimb of the Santa Fe Springs structure (Fig. 3). In the Quaternary, the narrow kink band (aa′) formed on the south margin of the fold, likely representing upward and southward propagation (reactivation) of this segment of the PHT.

The Quaternary growth structure of kink band aa′ exhibits an active anticlinal axial surface (a) that extends to the upper limit of industry seismic reflection profiles at about 300-m depth, and an inactive synclinal axial surface (a′) that bounds the other side of the growth triangle (Fig. 3) (Suppe *et al.*, 1992). High-resolution seismic reflection profiles acquired across the structure (Carfax site, Fig. 4) image the fold extending upward from 400 to ~25-m depth (Pratt *et al.*, 2002). Deformation of shallow, late Quaternary deposits is localized above the active, anticlinal axial surface. This growth geometry is consistent with development of the kink band by fault-bend folding (Suppe *et al.*, 1992; Shaw and Suppe, 1996; Pratt *et al.*, 2002) as the PHT flattens to an upper detachment in the central Los Angeles basin (Fig. 5). This interpretation implies that small amounts of displace-

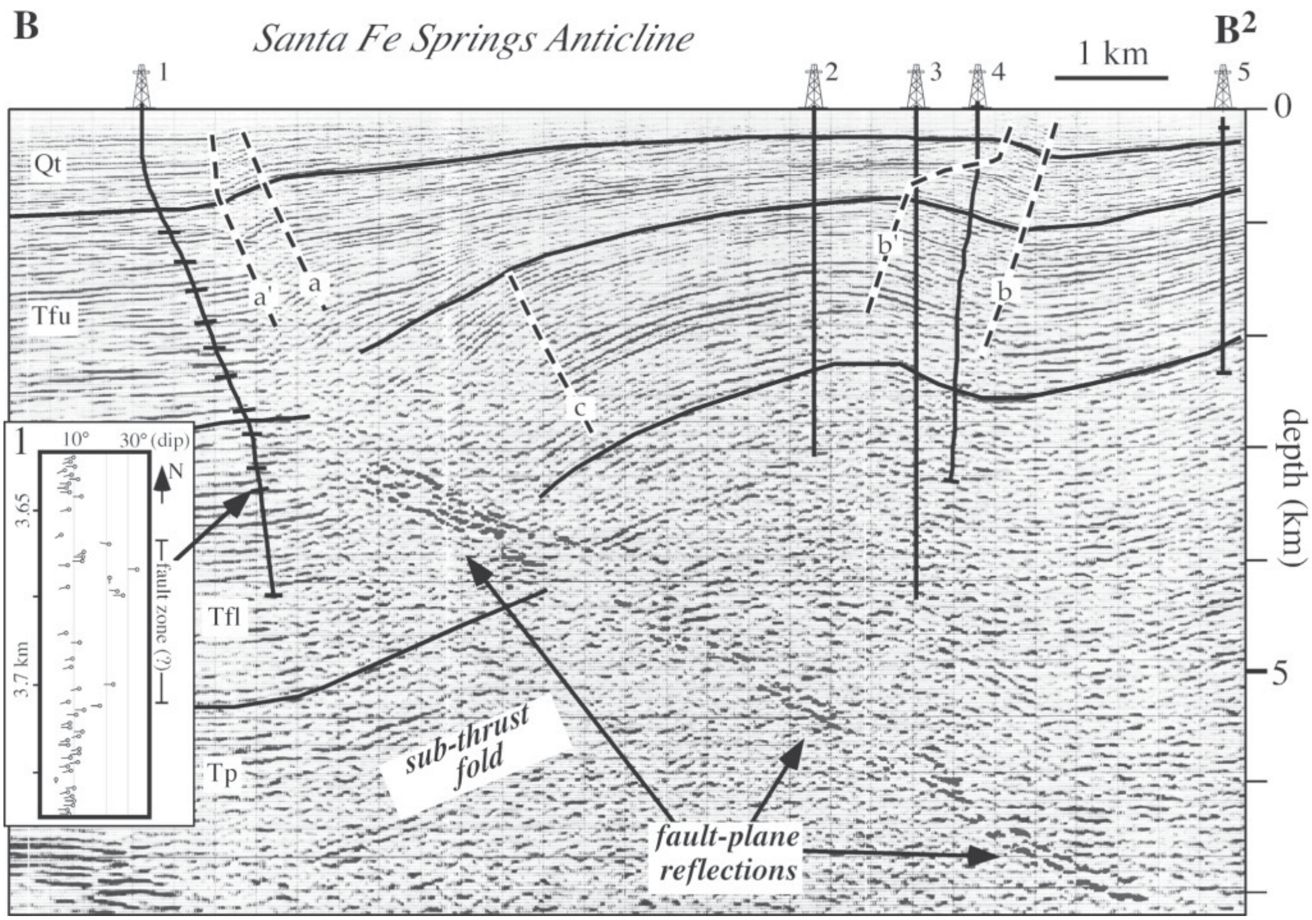

Figure 3. Migrated and depth converted seismic reflection profile across the Santa Fe Springs segment of the PHT after Shaw and Shearer (1999). The fold is bounded by kink bands (aa′; bb′) that narrow upward, forming growth triangles in the Quaternary section. The fault was interpreted and highlighted using an automated tracking technique that correlates reflections based on amplitude and lateral coherence within a given region and dip range. The inset shows a zone of chaotic bed dips at the interpreted upper detachment level in dipmeter log from the Union Bellflower #2 well. Profile traces are shown in Figure 1. Qt, Quaternary; Tfu, Pliocene upper Fernando Formation; Tfl, Pliocene lower Fernando Formation; Tp, Miocene Puente Formation. Wells: 1, Union Bellflower #2; 2, Chevron Newsome Community #1; 3, Chevron Houghton Community #1; 4, Conoco Felix #1; 5, Exxon Whittier #1.

ment (≤ 500 m) extend southward on this upper detachment into the central Los Angeles basin. The proposed detachment level is penetrated by the Union Bellflower #2 well (Fig. 3), which encountered a zone of chaotic dips at this location in an otherwise monotonous, gently southwest-dipping section.

The proposed multistage structural history of the Santa Fe Springs segment of the PHT is also recorded in the growth structure on the back limb of the anticline (Fig. 6). This structure contains another growth triangle. In contrast to the forelimb kink band, however, the backlimb growth triangle contains an active synclinal axial surface (b) and an inactive anticlinal axial surface (b′). This geometry is consistent with the backlimb structure forming above a subtle, steepening-upward bend in the PHT. Consistent with the forelimb interpretation, the backlimb growth structure defines a middle Pliocene phase of fold growth, followed by late Pliocene tectonic quiescence and a Quaternary period of reactivation.

The contoured fault-plane reflections define an east–west striking, 25°–29° N dipping Santa Fe Springs segment of the PHT (Fig. 1). Shaw and Shearer (1999) noted that this orientation matched the preferred nodal plane of the 1987 Whittier Narrow (M_w 6.0) earthquake (Hauksson and Jones, 1989). Using L-1 norm waveform cross-correlation techniques (Shearer, 1997) and velocity data derived from sonic logs, Shaw and Shearer (1999) relocated the earthquake and its aftershocks. The relocated cluster defined the dip of the preferred nodal plane and was positioned directly at the down-dip extension of the PHT imaged in the seismic reflection data (Fig. 5). This led Shaw and Shearer (1999) to conclude that the 1987 Whittier Narrows earthquake rup-

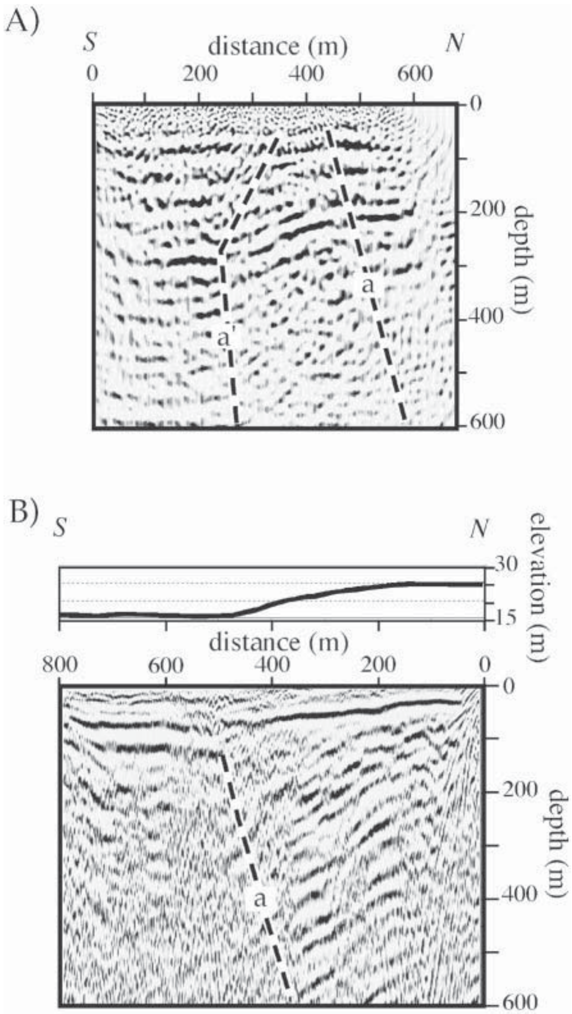

Figure 4. High-resolution seismic reflection profiles acquired with hammer drop and Mini-Sosie (Barbier, 1983) sources across the forelimbs that overlie the Santa Fe Springs (A, Carfax site) and Coyote Hills (B, Trojan Way site) segments of the PHT (Pratt *et al.*, 2002). Deformed strata corresponding to reflections in the shallow subsurface define late Quaternary activity on the PHT. Deformation is localized along active (a) axial surfaces, which correspond to the axial surfaces imaged in the industry reflection profile (Fig. 3, 6). Profile traces (C, Carfax; T, Trojan Way) are shown in Figure 1.

tured a small patch (~30 km^2) of the Santa Fe Springs segment of the PHT, demonstrating the activity and seismogenic potential of this blind-thrust system.

Coyote Hills Segment

The Coyote Hills segment of the PHT is defined by fault-plane reflections and reflection truncations in seismic profiles between 2- and 5-km depth beneath the western Coyote Hills anticline (Figs. 2, 6). Similar to the Santa Fe Springs structure, the Coyote Hills anticline is a broad, open fold bounded on its southern margin by a discrete forelimb kink band (aa′) that contains parallel, south-dipping (15°–30°) Pliocene strata. The fault extends upward to the base of this kink band, which is underlain by horizontal, relatively undeformed Miocene strata. Quaternary strata thin above this kink band in an apparent growth triangle, defining the age of fold growth and activity of the Coyote Hills thrust. This growth period initiates at a seismic sequence boundary that correlates with the beginning of the Quaternary growth phase on the Santa Fe Springs structure. In contrast to the Santa Fe Springs structure, however, the Coyote Hills kink band appears to contain an active synclinal axial surface (a) and an inactive anticlinal axial surface (a′) (Fig. 7). These observations are consistent with the fold geometry imaged in a high-resolution, Mini-Sosie profile (Trojan Way site, Fig. 4), which shows late Quaternary deformation localized above the synclinal axial surface (Pratt *et al.*, 2002). The syncline also corresponds with a surface fold scarp. This geometry is consistent with slip on the Coyote Hills thrust being entirely consumed in the kink band by some type of tip-line (fault-propagation) folding process (Suppe and Medwedeff, 1990; Allmendinger, 1998). Alternatively, the Coyote Hills thrust may shallow to an upper detachment from which a backthrust emanates, forming a structural wedge (Medwedeff, 1992).

A second, older seismic reflection survey images the Eastern Coyote anticline, including the steep kink band on the southern margin of the fold (Fig. 1). The older data, however, do not provide a direct image of the fault surface. We extrapolate the PHT beneath the Eastern Coyote Hills using the relationship between the fold and fault defined in the Western Coyote Hills. This includes positioning the fault at the base of the forelimb kink band as well as defining the dip of the fault as a function of bedding dip in the forelimb kink band. This yields a relatively simple, planar surface for the PHT beneath the Eastern Coyote Hills that dips to the north-northwest at about 25–30°. The strike of this fault segment mimics that of the Eastern Coyote Hills anticline, which is about N60°E (Wright, 1991), in contrast to the east–west strike of the Western Coyote Hills (Fig. 1). The fold geometries and the change in strikes imply that there is a shallow offset between the thrust ramps underlying the Western and Eastern Coyote Hills. When these two fault surfaces are projected to depth using a smoothed average of their dips, they intersect at relatively shallow crustal levels (~5 km). This suggests that the Eastern and Western Coyote Hills segment merge to a common basal ramp at this depth (Fig. 1). Alternatively, the fault segments may crosscut one another.

Based on our projections, the ramps of the Coyote Hills and Santa Fe Springs segments are separated by only a few hundred meters at depths below 8 km (Fig. 1). Thus, it is possible that these segments merge at depth to form a single, continuous ramp.

Los Angeles Segment

The Los Angeles segment of the PHT extends from the western margin of the Montebello Hills to about 5 km west

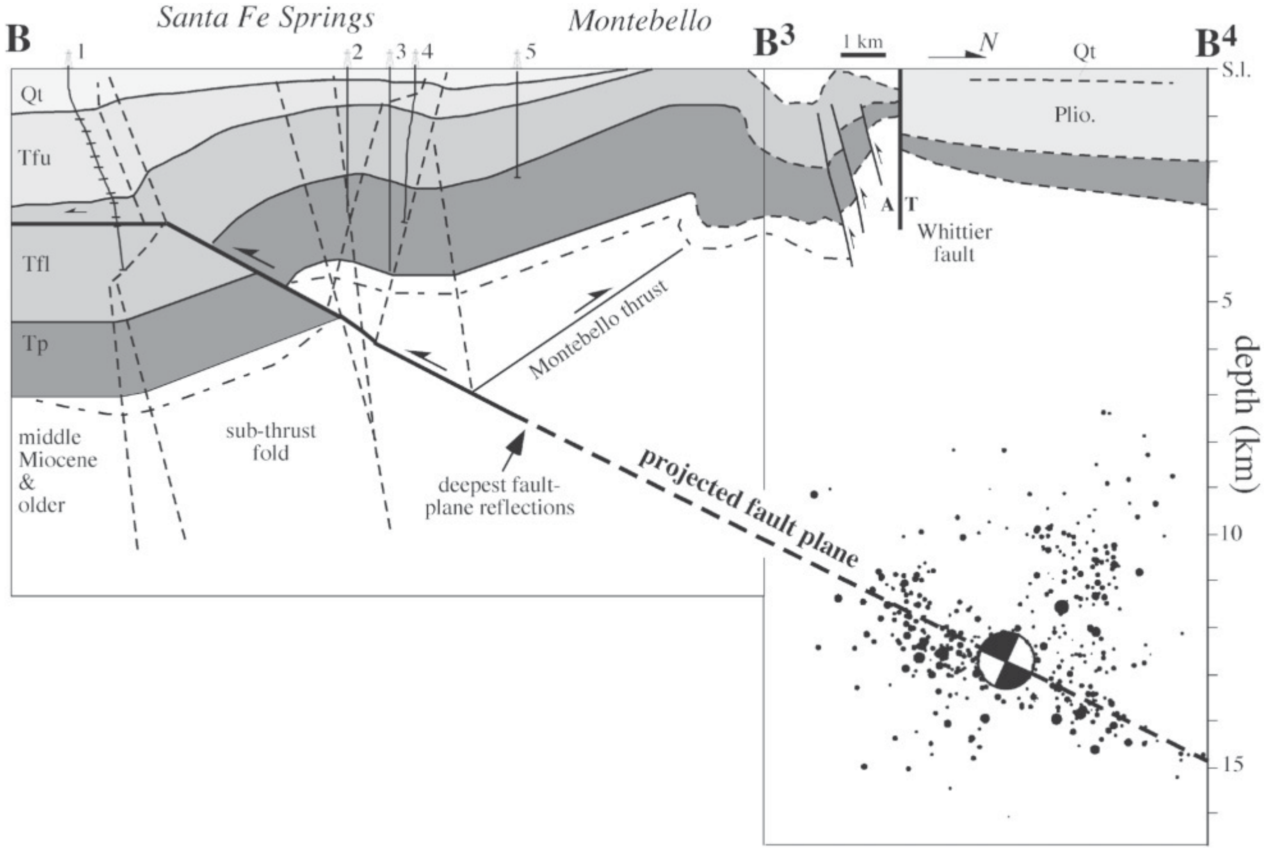

Figure 5. Geologic cross section showing relation of the Santa Fe Springs segment of the PHT to the hypocenters of the 1987 Whittier Narrows (M_w 6) earthquake and aftershocks after Shaw and Shearer (1999). The hypocenters were relocated by Shaw and Shearer (1999) using L-1 norm waveform cross-correlation techniques (Shearer, 1997) and velocity control from nearby oil wells. Profile trace is shown in Figure 1. Section B–B^3 is based on the seismic profile shown in Figure 3; section B^3–B^4 is based on Wright (1991). The subthrust fold is related to the lower Elysian Park trend of Davis *et al.* (1989). Formation symbols identified in caption for Figure 3.

of downtown Los Angeles (Fig. 1), which represents the westernmost extent of our seismic reflection data. The fold consists of a narrow kink band with south-dipping strata superimposed on a gently south-dipping monocline that forms the northern boundary of the central Los Angeles basin (Figs. 2, 8). Precise definition of the age of the kink band is difficult, as the section is poorly imaged above the base Quaternary sequence boundary that marks the initiation of growth in the Santa Fe Springs and Coyote structures (Fig. 2). Nevertheless, the Los Angeles segment kink band developed no earlier than this base Quaternary sequence boundary, as underlying upper Pliocene strata do not change thickness across the structure. In contrast, Quaternary strata thin above the structure. Thus, the kink band appears to have developed in the Quaternary, contemporaneous with the Santa Fe Springs and Coyote structures.

The Los Angeles segment of the PHT is defined by fault-plane reflections and reflection truncations at the base of the forelimb kink band in both north–south (Fig. 8) and east–west trending seismic profiles. In the eastern portion of the Los Angeles segment, the thrust ramp strikes east–west, generally parallel to the Santa Fe Springs and Western Coyote fault segments (Fig. 1). The western two-thirds of the Los Angeles segment, however, strike roughly N60°W. This portion of the Los Angeles segment also corresponds to a region where the tip of the thrust ramp, and the overlying kink band, are situated at the base of the broad monoclinal panel that forms the northern border of the central Los Angeles basin (Schneider *et al.*, 1996). Perhaps the southeast strike of this portion of the PHT was inherited from the trend of the preexisting monocline.

Quaternary Slip and Slip Rates

Quaternary slip on the PHT forms the discrete forelimb kink bands and produces structural relief of Quaternary strata above the three major thrust ramp segments (Fig. 9). As the fault system is blind and does not offset the base Quaternary horizon, we are unable to constrain fault slip by mapping stratigraphic offset. Thus, we employ two other

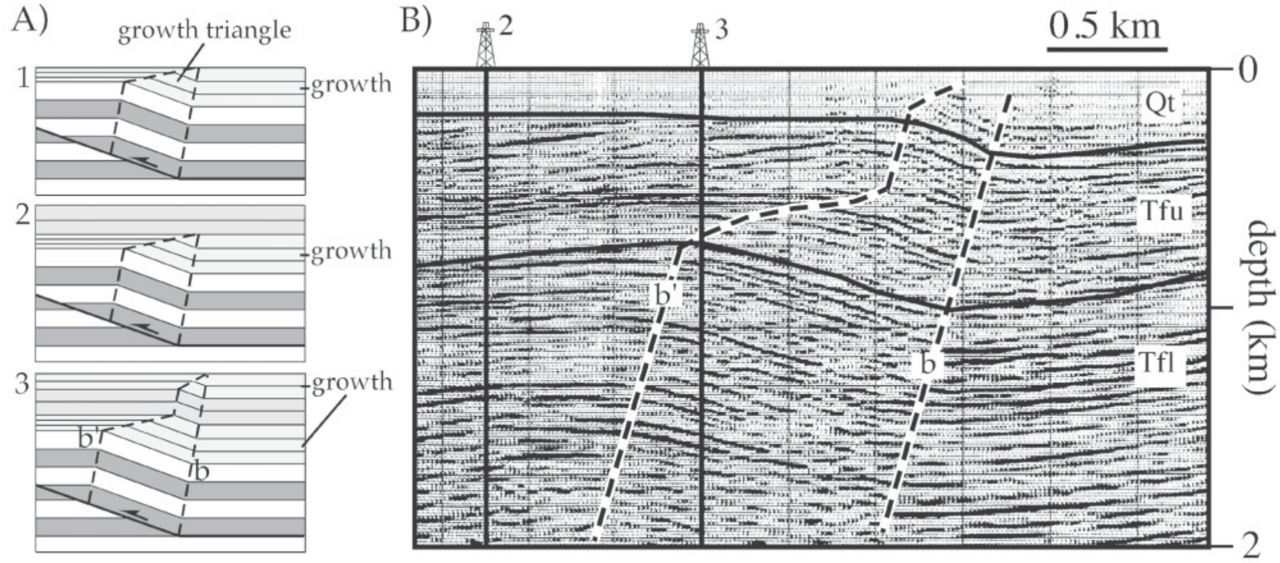

Figure 6. (A) Sequential kinematic model describing the evolution of a growth fault-bend fold (Suppe *et al.*, 1992). In model 1, slip across a synclinal fault bend produces a kink band that narrows upward in growth section (growth triangle). Model 2 depicts a period of deposition without fault motion. Model 3 shows reactivation of the fault, which extends the growth triangle upward into the shallow growth section. The reactivation history of the fault is recorded by inflections in the kink band's inactive axial surface (b′), which along with the active axial surface (b) bounds the growth triangle. (B) Depth-converted portion of the seismic profile in Figure 3 that images the backlimb growth triangle above the Santa Fe Springs fault segment. Inflections in the inactive axial surface (b′) are comparable to those modeled in A3 and record folding related to Pliocene activity, late Pliocene quiescence, and Quaternary reactivation of the underlying PHT. Formation symbols and wells identified in caption for Figure 3.

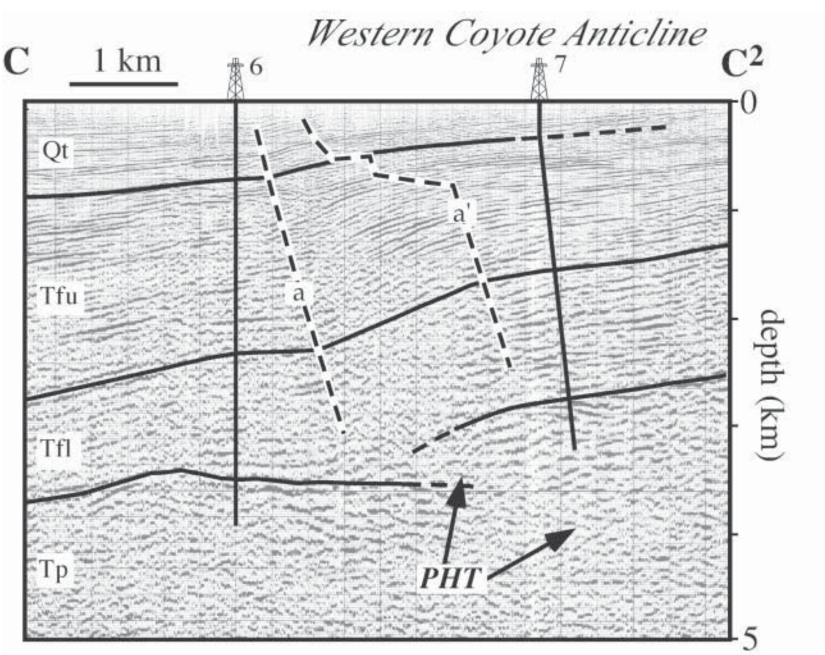

Figure 7. Migrated and depth-converted seismic reflection profile across the Coyote Hills segment of the PHT. The fault position is interpreted based on the downward termination of kink band aa′, reflection truncations, and structural relief of the Miocene and Pliocene strata. The fault terminates upward into the kink band (aa′), which narrows upward in Pliocene and Quaternary strata. Section trace is shown in Figure 1; stratigraphic nomenclature is described in Figure 3. Wells: 6, Chevron Rivera Community #1; 7, Westestates Santa Fe Springs #1.

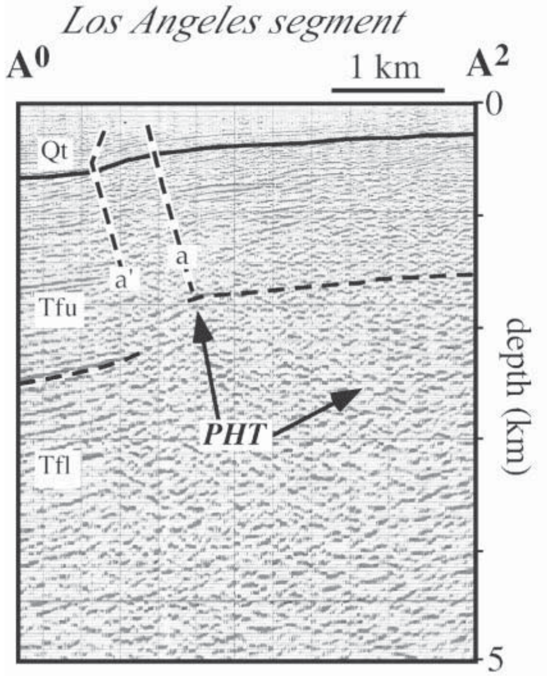

Figure 8. Migrated and depth-converted seismic reflection profile across the LA segment of the PHT. The fault position is interpreted based on the downward termination of kink band aa′, reflection truncations, and structural relief of the Miocene and Pliocene strata. Section trace is shown in Figure 1; stratigraphic nomenclature is described in Figure 3. Stratigraphic horizons are correlated from well control along the profile from the south.

techniques to map fault displacement. The first method uses measures of total structural relief across the anticlinal forelimb and the fault dips to calculate reverse slip (Fig. 10A). This method is straightforward, yet can be affected by primary sedimentary dip and cannot be used to distinguish whether a single or multiple thrust ramps contribute to the uplift. The second method (Fig. 10B) uses a measure of the width of the forelimb kink band as a measure of fault slip (Shaw and Suppe, 1994, 1996). Most kinematic models of fault-related folding imply some relation between kink-band width and fault slip; however, the conversion between these properties is specific to the kinematic model. For example, in fault-bend folds, including some classes of wedge structures, forelimb width is generally within 20% of fault dip slip (Suppe *et al.*, 1992) and can be calculated more precisely if fault orientation is known (Suppe, 1983).

Structural relief and kink-band widths were measured above the three ramp segments, with only the eastern portion of the Coyote segment omitted due to a lack of sufficient data. The fold width and uplift measurements track closely, generally being within 10% of one another (Fig. 11A). The similar shapes of the profiles imply that both kink-band width and uplift measurements reflect slip. We convert these measurements to fault slip estimates based on the following considerations. Structural relief is converted to maximum and minimum dip slip based on the minimum and maximum fault dip values (20° and 40°), respectively (Fig. 11B). This conservative fault-dip range takes into account all of the dip values observed on the seismic reflection data and the uncertainties in the velocity model used to depth convert the seismic sections. In order to calculate these maximum and minimum dip-slip values, we assume that uplift across the fold is equal to the fault heave. The conformable geometry of upper Pliocene pregrowth units across the fold crest observed in the seismic data (Figs. 2, 3) supports this assumption. The stratal geometry also implies that primary sedimentary dip did not significantly influence the structural relief measurement.

Using the same method, we calculated preferred slip values for the three fault segments (Fig. 11B) using a 27° N dip value. This dip value is based on the average ramp dip observed in the seismic data on all three segments and the linkage of the Santa Fe Springs segment to the 1987 Whittier Narrows (M_w 6.0) mainshock (Shaw and Shearer, 1999). Taking into account the uncertainty in the hypocentral location, we estimate that this dip value is correct within ±2° for the central portion of the Santa Fe Springs segment.

To evaluate the alternative slip estimation method, we converted the forelimb kink-band width of the Santa Fe Springs structure to slip using the fault dip value of 27°. The conversion is based on our interpretation of the forelimb kink-band at Santa Fe Springs as a fault-bend fold (Suppe, 1983). The fold kinematics are poorly constrained on the Coyote Hills and Los Angeles segments, so we did not consider these faults in this analysis. Fault-bend fold theory defines the ratio of slip (R) on the upper detachment and the fault ramp. Slip on the upper detachment is equal to kink-band width. For a 27° ramp dip, R is 0.73. The slip profile based on kink-band width tracks closely with the slip estimate based on uplift, reaching a maximum in the center of the trend and decreasing toward both segment boundaries (Fig. 11B). However, the slip derived from kink-band width generally underestimates the slip based on structural relief by about 25% for the same ramp dip. Underestimation of slip based on the kink-band width may reflect the fact that this method only considers slip that passes over the fault bend. Thus, it does not account for slip on the ramp that may be consumed by the broad anticlinal warping of the hanging wall (Figs. 3, 6, 7), which is taken into account by the slip calculation based on the total uplift.

All of the slip profiles exhibit patterns with maximum slip near the center of the fault segments (Fig. 11B). Slip tapers off toward the segment boundaries. Overlapping slip profiles across the segment boundaries imply that the fault segments are en echelon, meaning that they overlap one another along the north–south transport direction. The slip profiles suggest that slip is gradually transferred from one segment to the next. This slip pattern and fault geometry are consistent with a soft linkage among the ramp segments (Fig. 12A).

The fault-slip estimates can be used to calculate aver-

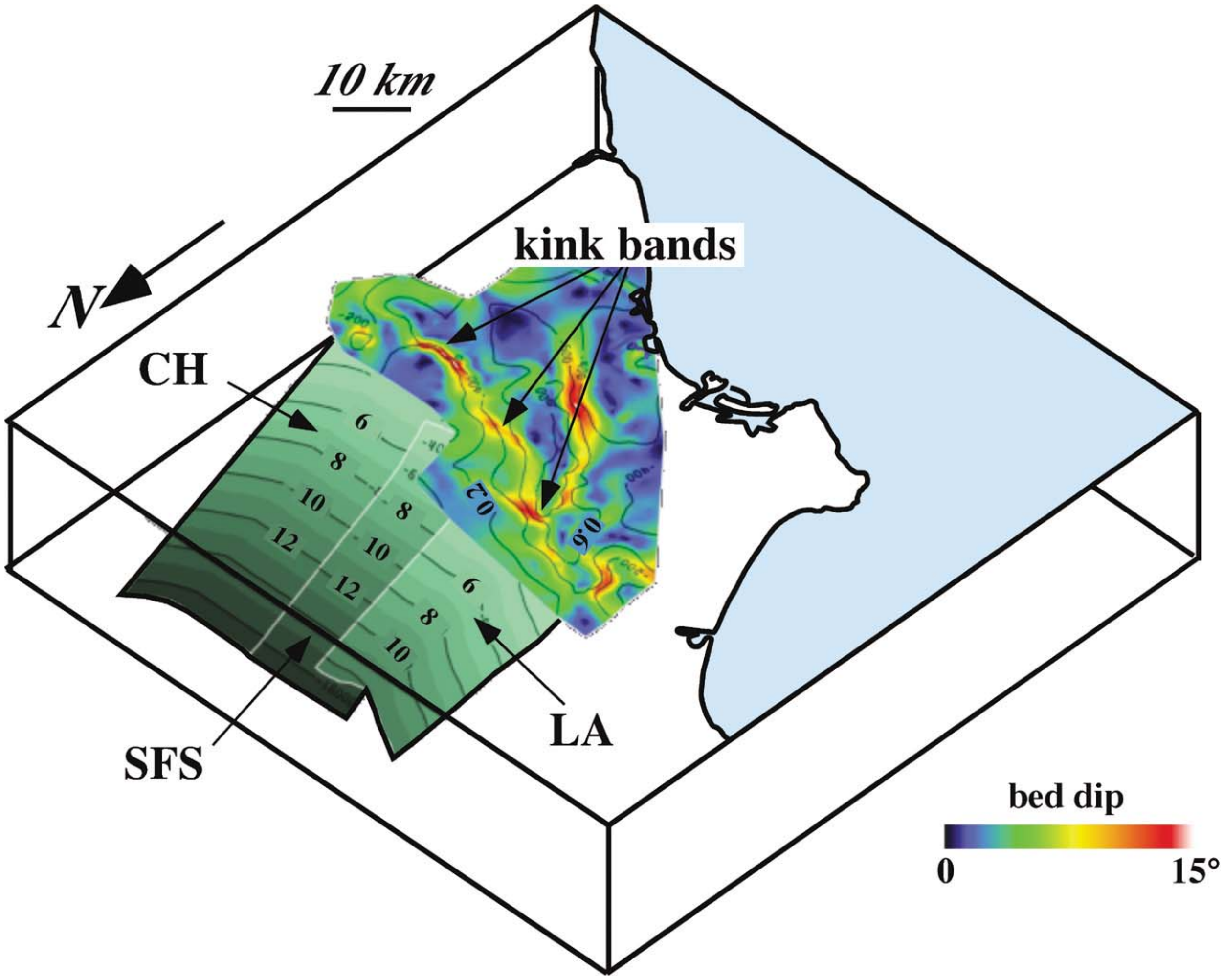

Figure 9. Perspective view of a three-dimensional model of the PHT and the overlying base Quaternary stratigraphic surface. The base Quaternary surface is folded by motion on the PHT, as reflected by the band of steep bed dips (color coded) in the forelimb kink bands. Contours are in kilometers subsea. CH, Coyote Hills segment; SFS, Santa Fe Springs segment; LA, Los Angeles segment.

age, long-term slip rates given the age of the sequence boundary that marks the initiation of Quaternary fold growth (Fig. 2). The base Quaternary horizon marks a transition from Quaternary nonmarine to Pliocene inner neritic strata. The boundary locally corresponds with the base of the La Habra sequence and the top of the Wheelerian benthic foraminiferal stage and is widely reported in oil wells (Blake, 1991; Wright, 1991). The precise age of this sequence boundary is not known, so we use an estimate of the maximum age of the top Wheelerian stage (1.6 Ma) (Blake, 1991) to make conservative slip-rate estimates. Based on this age, we calculate long-term slip rates on the portion of each PHT segment that has the greatest total slip. Ranges are provided based on the slip calculated using measured uplift and the minimum (20°) and maximum (40°) fault-dip values. The preferred rate is based on a 27° fault dip. For the Santa Fe Springs segment, the range of slip rates is 0.44–0.82 mm/yr, with a preferred rate of 0.62 mm/yr. The slip rate estimate for the Los Angeles segment is 0.60–1.13 mm/yr, with a preferred rate of 0.85 mm/yr. The Coyote segment has a faster slip rate, ranging from 0.90 to 1.70 mm/yr with a preferred rate of 1.28 mm/yr. These slip rates imply that the PHT accounts for 10%–25% of the shortening across the northern Los Angeles basin measured by geodesy (Argus *et al.*, 1999; Bawden *et al.*, 2001).

Systematic Behavior of the PHT Segments

Our geometric modeling and fault-slip analysis provide insights into the systematic behavior of the PHT. The three main segments of the PHT form an en echelon set of thrust ramps, with two major geometric segment boundaries separating the three fault ramps (Fig. 1). Slip appears to have initiated on all three fault segments in the early Quaternary (Fig. 2) based on the forelimb growth structures. The defined slip patterns mimic the observed uplift and kink-band widths

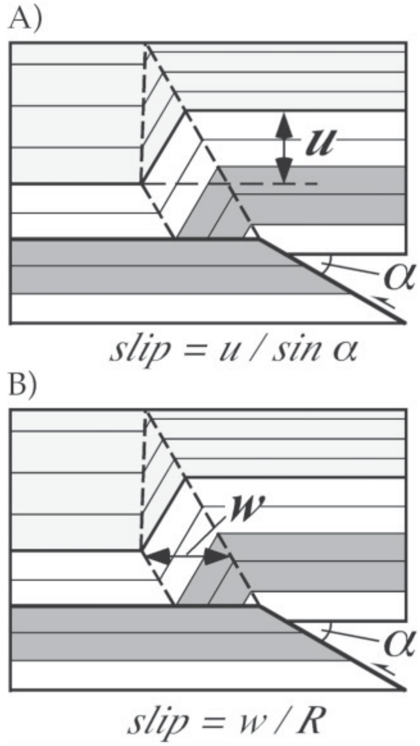

Figure 10. Fault-related fold models describing two methods of estimating fault slip. (A) Fault dip slip is derived from structural relief (*u*) and fault dip (α). (B) Fault dip slip is derived from kink-band width (*w*) and fault dip (α) using a conversion factor (*R*) derived from applicable fault-related folding theories.

and imply that slip is greatest near the center of each segment and decreases toward the segment boundaries (Fig. 11). Overlapping slip zones at the segment boundaries imply that displacement is transferred from one ramp segment to the next in an en echelon manner (Fig. 12A), rather than by a discrete tear fault (Fig. 12B). As slip decreases on one segment, slip on the adjacent segment increases. This soft-linkage pattern implies that thrust ramps overlap one another along the transport direction, which is consistent with the mapped fault surfaces (Fig. 1).

The measured uplift and kink band width on the three fault segments suggests that slip on the Santa Fe Springs segments is less than slip on the Los Angeles and Coyote segments (Fig. 11). This may be due to the presence of the south-dipping Montebello thrust (Figs. 1, 5), which lies north of the Santa Fe Springs fault segment. The Montebello thrust must intersect the Santa Fe Springs thrust ramp at depth and is either offset by the PHT or merges with it, forming a structural wedge (Medwedeff, 1992). In the latter scenario, slip on the PHT is partitioned between the south-dipping Montebello thrust fault and the north-dipping Santa Fe Springs ramp (Fig. 5). Thus, slip on the Santa Fe Springs ramp that we measured could be less than slip on the deeper portion of the PHT that lies north of its intersection with the Montebello thrust. As the Montebello backthrust is limited to the Santa Fe Springs segment, slip calculated on the Coyote and Los Angeles segments should reflect directly motion on the PHT at depth.

Slip appears to decrease to the west on the Los Angeles fault segment (Fig. 11). This may reflect oblique slip on the northwest–southeast trending portion of the Los Angeles fault segment (Fig. 1), leading to less dip slip in the west. Alternatively, or in addition, the Los Angeles segment of the PHT may have propagated to the west during the Quaternary, leading to less total slip on the western reaches of the fault system.

PHT in Relation to Other Faults in the Northern Los Angeles Basin

In addition to the PHT, the northern Los Angeles basin is deformed by several other large blind-thrust and strike-slip fault systems. We briefly summarize the relation of the PHT to these other fault systems because these relationships are critical for seismic hazard assessment.

The northern Los Angeles basin is located at the juncture of the Transverse and Peninsular Range Provinces and therefore contains both east–west and northwest–southeast structural trends. East–west trending structures are generally associated with the Transverse Range Province; whereas, northwest–southeast trending faults are ascribed to the Peninsular Range Province. The PHT represents the southernmost of the east–west trending fault systems, and thus we consider it to be the southern limit of the Transverse Ranges Province. Several other blind-thrust systems lie to the north and in the hanging wall of the PHT (Fig. 13, 14). These include the Las Cienegas and San Vicente faults (Wright, 1991; Schneider *et al.*, 1996), the (upper) Elysian Park thrust as described by Oskin *et al.* (1999), and the Santa Monica fault (Wright, 1991; Dolan *et al.*, 1995, 2000; Tsutsumi *et al.*, 2001). This part of the basin is also deformed by active, east to east–northeast trending strike-slip systems, including the Hollywood and Raymond faults (Dolan *et al.*, 1995, 1997; Walls *et al.*, 1998). The Cienegas fault (Schneider *et al.*, 1996) intersects the Los Angeles segment of the PHT at a depth of about 5 km. Thus, the Cienegas fault either merges with, or is offset by, the PHT. The Cienegas fault was active in the Pliocene but exhibits little or no evidence for Quaternary motion (Schneider *et al.*, 1996). This suggests that the younger PHT may have cut, and consequently rendered inactive, the Las Cienegas fault in the early Quaternary. None of the other major thrust faults in the northern basin intersect the PHT at shallow depths.

Several northwest–southeast trending fault systems associated with the Peninsular Range Province also occupy the northern Los Angeles basin. These structures include the (lower) Elysian Park thrust (EPT) (Davis *et al.*, 1989; Shaw and Suppe, 1996), the Anaheim Nose (Wright, 1991), and the Newport–Inglewood and Whittier strike-slip systems (Fig. 13). The lower EPT was inferred from the presence of a large, deeply rooted monoclinal fold panel that forms the

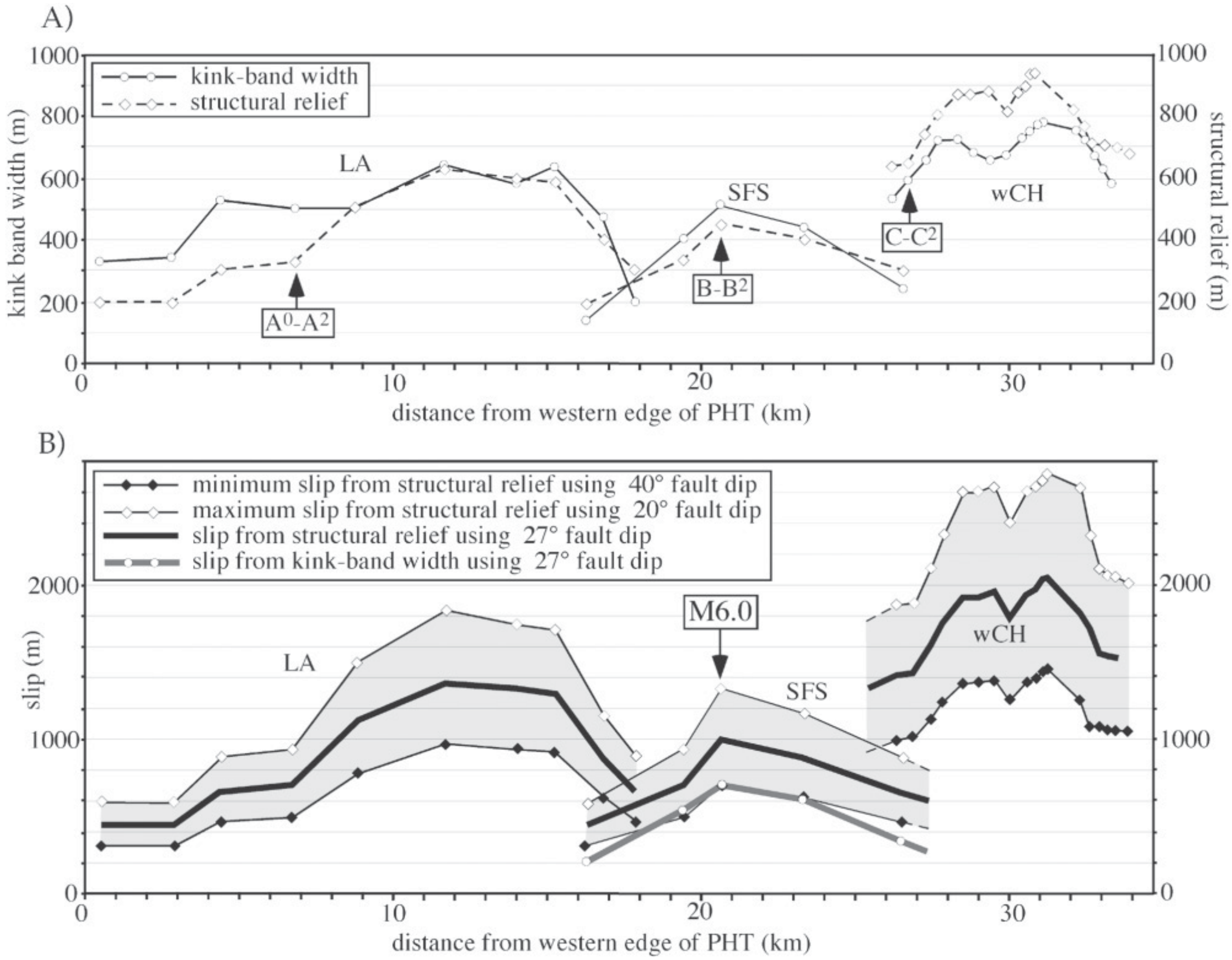

Figure 11. (A) Plot of kink-band width and structural relief measured from depth converted seismic profiles across the forelimbs that overlie the PHT. A^0–A^2, B–B^2, and C–C^2 denote positions along the profiles corresponding to the seismic sections presented in Figures 2, 3, 7, and 8. (B) Structural relief and kink-band width converted to slip using the methods described in Figure 10 and preferred (27°) and conservative (20 to 40°) fault-dip estimates.

northern border of the central Los Angeles basin. The Los Angeles and Santa Fe Springs segments of the PHT extend across, and offset, the upper portion of this fold trend (Fig. 3). Thus, the PHT lies above the lower Elysian Park thrust (Figs. 13, 14). The two fault ramps also have different strikes and slip histories (Davis *et al.*, 1989; Shaw and Suppe, 1996). This implies that the PHT and lower EPT are distinct fault systems and must be considered as separate potential earthquake sources.

The Whittier fault system extends across the Santa Fe Springs and Coyote Hills segments of the PHT (Fig. 13). The largest aftershock (local magnitude [M_L] 5.3) of the 1987 Whittier Narrows earthquake had a right-lateral, strike-slip focal mechanism (Hauksson and Jones, 1989). Based on the relocated aftershock cluster (Shaw and Shearer, 1999), it appears that this event occurred on a northwestern splay of the Whittier fault system (Fig. 13), perhaps the East Montebello fault (Wright, 1991). This secondary rupture was limited to the hanging wall of the Santa Fe Springs segment of the PHT, which extends downdip beneath the ruptured splay of the Whittier fault (Fig. 5). Thus, the strike-slip fault is either limited to the hanging wall of the PHT or is offset at depth by the thrust with displaced hanging-wall and footwall segments. Both scenarios imply that these two major fault systems are in contact within the seismogenic crust and, therefore, may have linked slip and rupture histories.

Regional Earthquake Hazards

The PHT extends for more than 40 km across the northern LA basin and directly underlies the downtown area (Fig. 1). The 1987 Whittier Narrows M_w 6.0 earthquake and folded late Quaternary deposits above the fault tip line (Fig. 4) demonstrate that the fault is active. The deformation im-

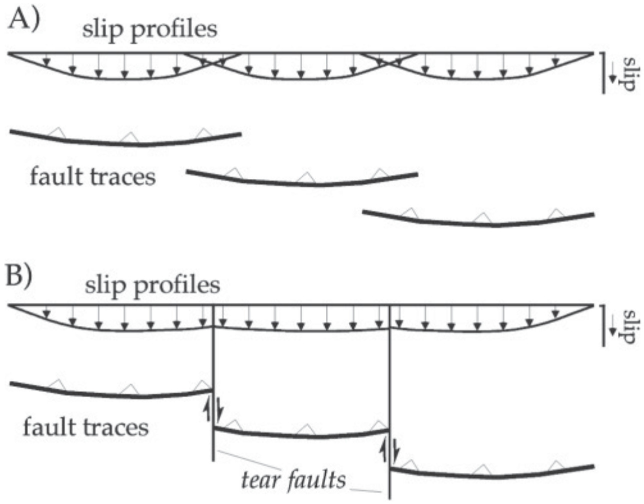

Figure 12. (A) Schematic, map-view slip profiles and fault traces diagnostic of a soft-linkage style of thrust segmentation. The fault traces overlap in an en echelon manner, and slip is gradually transferred from one fault segment to the next. (B) Schematic, map-view slip profiles and fault traces diagnostic of a hard-linkage style of thrust segmentation. The thrust traces terminate into tear faults, which abruptly transfer slip from one thrust segment to the next.

aged in the high-resolution seismic reflection data (Pratt *et al.*, 2002) also imply that past earthquakes have produced discrete folds at the Earth's surface (King and Vita-Finzi, 1981), similar to structures developed during the 1999 Chi Chi (M_w 7.7) earthquake in Taiwan (Suppe *et al.*, 2000). As discrete surface folding of this type did not occur during the 1987 M_w 6.0 event, we suggest that larger earthquakes capable of near-surface folding have occurred on the PHT in the past. These events may have been single or multisegment ruptures of the PHT (Shaw and Shearer, 1999). To estimate the sizes of these earthquakes, we calculate the area of the fault ramps between 5- and 17-km depth and use empirical relations that relate rupture area to earthquake magnitude (Wells and Coppersmith, 1994). The three fault surfaces have areas of 370 (Los Angeles), 260 (Santa Fe Springs), and 380 (Coyote) km^2. Based on the en echelon, soft-linkage nature of PHT fault segments (Fig. 12A) and the separation of the fault ramps at depth (Fig. 1), it seems possible that the fault segments can rupture independently. If these segments ruptured completely in separate earthquakes, the Los Angeles and Coyote segments would produce M_w 6.6 earthquakes and the Santa Fe Springs segment would produce a M_w 6.5 earthquake. These single segment earthquakes may occur in closely spaced sequences. This behavior has been well documented in a similar en echelon blind-thrust system in central California, which ruptured in the 1981 New Idria (M_w 5.4), 1983 Coalinga (M_w 6.5), and 1985 Kettleman Hills (M_w 6.1) earthquake sequence (Stein and Ekstrom, 1992). The similar fault geometries, slip rates, and slip histories of the three PHT segments, however, suggest that large multisegment ruptures are also possible. Simultaneous rupture of all three PHT segments would produce a M_w 7.1 earthquake.

Based on the average Quaternary fault-slip rates and empirical estimates of coseismic displacement for thrust earthquakes (Wells and Coppersmith, 1994), we calculate the average repeat times for our single and multisegment rupture scenarios. The range of repeat times for a given earthquake scenario are based on the range of fault-slip rates. Single-segment (M_w 6.6) ruptures on the Los Angeles and Coyote segments have average repeat times of 540–1000 years and 400–600 years, respectively. Earthquakes limited to the Santa Fe Springs segment (M_w 6.5) would rupture every 720–1320 years. Average repeat time on the Santa Fe Springs segment may be more similar to those on the other segments if the Montebello thrust branches from the PHT and consumes slip, as discussed previously. Potential M_w 7.1 multisegment ruptures would occur less frequently, with a repeat time of 780–2600 years. Single or multisegment earthquakes would cause extensive damage to metropolitan Los Angeles (Heaton *et al.*, 1995) based on the experience of the 1994 Northridge (M_w 6.7) earthquake (Scientists of the U.S. Geological Survey [USGS] and Southern California Earthquake Center [SCEC], 1994). The Northridge earthquake occurred on a blind-thrust fault beneath a northern suburb of Los Angeles and was similar in source type and magnitude to the single-segment earthquake scenarios proposed for the PHT. The Northridge event caused more than $40 billion dollars in property damage (Eguchi *et al.*, 1998). The PHT represents three potentially independent sources capable of generating similar earthquakes directly beneath metropolitan Los Angeles.

Conclusions

Over the past two decades, scientists have debated the existence and earthquake potential of blind-thrust faults beneath LA. The PHT offers the first compelling image of an active, seismogenic blind-thrust fault beneath metropolitan Los Angeles, confirming that such faults pose credible earthquake hazards. The fault is imaged in seismic reflection profiles acquired by the petroleum industry and is considered the source of the 1987 Whittier Narrows (M_w 6.0) earthquake (Shaw and Shearer, 1999). The fault comprises three distinct fault segments that extend beneath metropolitan Los Angeles. Each segment is overlain by a discrete forelimb kink band. These kink bands were imaged by industry and high-resolution seismic data and extend from about 3-km depth to the shallow subsurface (<15 m) where they deform late Quaternary strata. These observations confirm that the PHT is active and imply that it is capable of generating large earthquakes that produce surface fold scarps.

We applied two methods to estimate Quaternary fault displacement on the PHT, one based on uplift and the other based on fold-limb (kink-band) width. Both methods yielded slip profiles that are greatest in the center of each segment

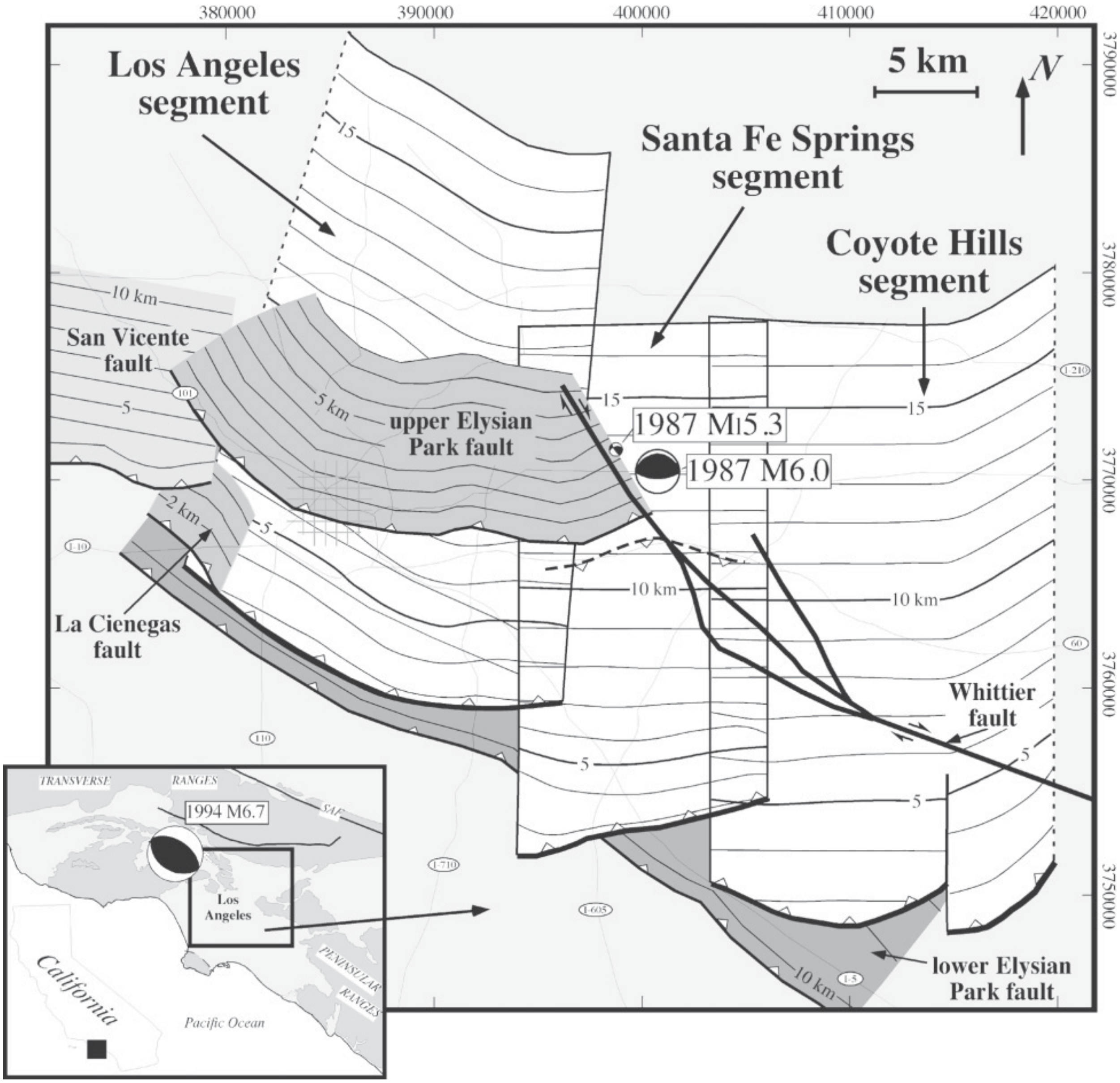

Figure 13. Structure contour map of the PHT in relation to other major thrust and strike-slip systems in the northern LA basin. Contour interval is 1 km; depths are subsea. Map coordinates are UTM Zone 11, NAD27 datum.

and that decrease toward the segment boundaries. These slip profiles, combined with the mapped fault geometry, imply that the PHT contains soft-segment boundaries. Soft-segment, or en echelon, fault systems are characterized by ramps that overlap along the transport direction and by displacement profiles in which slip is gradually transferred from one segment to another across the segment boundaries. The nature of these segment boundaries and the sizes of the fault ramps suggest that the PHT segments could rupture separately in M_w 6.5–6.6 earthquakes. Alternatively, these segments could rupture in larger, multisegment (M_w 7.1) earthquakes.

We calculated long-term average slip rates for each segment of the PHT based on the fault-slip estimates and an estimate of the age of thrust initiation in the early Quaternary. Slip rates range from 0.44 to 1.7 mm/yr, with preferred rates of 0.85, 0.62, and 1.28 mm/yr on the Los Angeles, Santa Fe Springs, and Coyote segments, respectively. These rates imply that the PHT accounts for 10% to 25% of the shortening across the northern Los Angeles basin that is measured by geodesy (Argus *et al.*, 1999; Bawden *et al.*, 2001). These slip rates suggest that, on average, single segment earthquakes (M_w 6.5–6.6) could occur on each segment about every 400 to 1320 years; whereas, multisegment (M_w

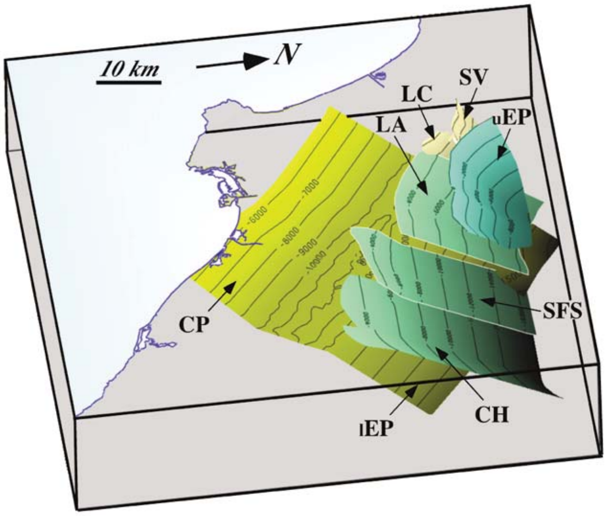

Figure 14. Perspective view of a three-dimensional model describing the PHT in relation to other major blind-thrust systems in the northern Los Angeles basin. PHT segments: CH, Coyote Hills; SFS, Santa Fe Springs; LA, Los Angeles segment; SV, San Vicente fault; LC, Las Cienegas fault (Schneider *et al.*, 1996); uEP, upper Elysian Park thrust (Oskin *et al.*, 2000); lEP, lower Elysian Park (Davis *et al.*, 1989; Shaw and Suppe, 1996); CP, Compton ramp (Shaw and Suppe, 1996).

7.1) earthquakes could occur with repeat times of 780–2600 years. As shown by the 1994 Northridge (M_w 6.7) event, earthquakes of these magnitudes would cause severe damage in the LA metropolitan area.

Acknowledgments

This research was supported by the National Earthquake Hazards Reduction Program (Grant 01HQGR0035), SCEC, and the National Science Foundation (EAR-0087648). The authors thank Michelle Cooke, Karl Mueller, Tom Rockwell, and Tom Wright for their helpful insights and John Suppe and Robert S. Yeats for constructive reviews.

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ATTACHMENT G

SAFETY ELEMENT

DEPARTMENT OF CITY PLANNING LOS ANGELES, CALIFORNIA

City Plan Case No. 95-0371
Council File No. 86-0662

SAFETY ELEMENT
OF THE LOS ANGELES CITY GENERAL PLAN

Relates to Natural Hazards, Not Police Matters

Replaces the 1975 Safety, 1974 Seismic Safety and 1979 Fire Protection & Prevention Elements

Approved by
the City Planning Commission
August 8, 1996

Adopted by
the City Council
November 26, 1996

CITY OF LOS ANGELES
Richard Riordan, Mayor

CITY COUNCIL
1st District - Mike Hernandez
2nd District - Joel Wachs
3rd District - Laura N. Chick
4th District - John Ferraro
5th District - Michael Feuer
6th District - Ruth Galanter
7th District - Richard Alarcón
8th District - Mark Ridley-Thomas
9th District - Rita Walters
10th District - Nate Holden
11th District - Marvin Braude
12th District - Hal Bernson
13th District - Jackie Goldberg
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CITYWIDE PLANNING DIVISION
R. Ann Siracusa, AICP, Principal City Planner

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GRAPHICS SERVICES SECTION
Rey Hernandez, Graphic Designer III
Michael Uhlenkott, Graphic Designer II

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INTRODUCTION

State law since 1975 has required city general plans to include a safety element which addresses the issue of protection of its people from unreasonable risks associated with natural disasters, *e.g.*, fires, floods, earthquakes. It did not intend that a safety element address police matters, except in the context of natural disasters. In 1984, the State deleted the seismic safety element from its list of mandated general plan elements and incorporated the seismic provisions under the safety element provisions. The subject Safety Element provides a contextual framework for understanding the relationship between hazard mitigation, response to a natural disaster and initial recovery from a natural disaster. It replaces three previously adopted elements of the City's General Plan: the Safety Element, Fire Protection and Prevention Element, and Seismic Safety Element.[1] All three have been revised and combined into the subject Element. Drainage, water and fire facilities will be addressed in greater detail by facilities or infrastructure elements of the General Plan.

An important premise of the Safety Element is that Los Angeles is a built city that is integrally connected to its neighbors geographically and by natural disasters which recognize no boundaries. Therefore, the Element outlines the historic evolution in Los Angeles of local, state and federal roles, particularly relative to mitigation of and response to natural disasters. The last section of the Element contains goals, objectives, policies and broadly stated programs. The programs outlined are programs of the City Emergency Operations Organization (EOO). The EOO is the City agency (program) which implements the Safety Element.

Following the 1994 Northridge and 1995 Kobe, Japan earthquakes a variety of studies and cooperative information exchange ventures were initiated to expand knowledge concerning earthquakes so that people could be better protected in the event of future significant seismic events. Kobe, Northridge and other seismic event information is being used in formulating methodologies for strengthening buildings and structures to more successfully withstand severe damage and to better protect occupants and equipment during various types and degrees of seismic events.

The California State Geologist's Seismic Hazards Mapping Program is preparing the State's official seismic hazard maps. The maps will identify amplified shaking, liquefaction and landslide hazard zones. Once the maps become available they will be used in revising the City's building, zoning and other codes, plans, standards, procedures and/or development permit requirements.

Chapters I and III of this Safety Element outline the scope of the EOO's on-going efforts to use experiences and new information to improve the City's hazard program. Chapter II outlines the City's historic commitment to improving its prevention of controllable disasters, mitigation of impacts associated with disasters and response to disaster events.

[1] *Adopted by the City Council on September 19, 1975, January 16, 1979 and September 10, 1974, respectively.*

CHAPTER I - BACKGROUND

PLANNING AREA

The Safety Element relates to the entire City of Los Angeles. Within the City's boundaries are approximately 465 square miles of land area, including approximately 214 square miles of hills and mountains. The San Gabriel and Santa Susana Mountains bound the City on the north, the Santa Monica Mountains extend across the middle of the City. The Palos Verdes Hills and Pacific Ocean are on the south and west. Because flood, fire and seismic events, geologic features and potential hazards relate to each other and transcend the City's boundaries, this Element takes into account other jurisdictions and governmental entities.

DEMOGRAPHICS

The 1990 Federal census estimated that the City's population was 3,485,399 individuals. The 1995 General Plan "Framework" element estimated that the population of Los Angeles City would be increased by approximately 820,000 people to 4,306,564[2] and that employment would be increased by an estimated 390,000 jobs by the year 2010.

EMERGENCY OPERATIONS ORGANIZATION AND OTHER INTERAGENCY COORDINATION

Emergency Operations Organization (EOO). The EOO is the City agency that implements the Safety Element. Therefore, it is the only "program" identified by the Element. The EOO is a unique City department, as indicated in the following.

EOO background and history. After every significant emergency, City personnel evaluate the effectiveness of response, ways to improve response and how to reduce potential loss of life, injury and property damage in future similar events. Natural disasters within the City, as well as disasters in other parts of the world, have added to existing knowledge about disaster preparedness. Historically most jurisdictions rely on emergency personnel (police, fire, gas and water) to respond to and handle emergencies. In many jurisdictions, emergency agencies work independently of one another; situation which can lead to command and effectuation conflicts and inefficiencies.

In the late 1970s it was recognized that Los Angeles enjoyed a significant number of public and private resources which could be mobilized to respond to emergencies and provide assistance to victims. However, most of the services operated independently of each other. To evaluate how to make better use of government and private resources, Mayor Tom Bradley convened a task force to study the situation and recommend a plan of action. The task force recommended establishment of a unified, streamlined chain of command to maximize the limited City resources which were available for response to emergency situations. To accomplish this goal the City, in 1980, adopted the Emergency Operations Ordinance (Ordinance No. 153,772) which established a multi-agency Emergency Operations Organization (EOO) under the direction of the Mayor and administration of an Emergency Operations Board (EOB). At the time, it was the only city organization of its kind in the United States.

EOO description. The EOO is an operational department of the City pursuant to City Administrative Code Division 8, Chapter 3. It is a "department without walls" which is comprised of all agencies of the City's government. However, unlike traditional departments, the EOO is not located physically in any one place. It is a chain of command and protocols which integrate the City's emergency operations into a single operation. It centralizes command and information coordination so as to enable the chain of command to operate efficiently and effectively in deploying resources.

The Emergency Operations Board (EOB) supervises the EOO (*i.e.*, City) emergency preparedness, response and recovery. It is comprised of the heads of the City's critical emergency operations agencies, *e.g.*, Board Public Works, Fire and Police departments, *etc.* The Chief of Police is chair of the EOB, the City Administrative Officer is the vice chair responsible for coordinating non-emergency EOO activities and the City Attorney is the legal advisor

[2] *The figure is consistant with the estimate used by the Southern California Association of Governments.*

to the EOB. The Mayor, in time of emergency, directs the 13 operational divisions of the EOO. Each division is responsible for carrying out specific tasks for coordinating emergency actions which are essential in abating the impacts and limiting the scope of a catastrophe; responding to life threatening situations and safety needs of the population; maintaining and reestablishing essential services, transportation and communication networks; aiding dislocated people; and planning for recovery. Various City agencies are responsible for coordinating the activities of their assigned divisions. For example, the EOO ordinance specifies that the Transportation Division is under the responsibility of the general manager of the City Department of Transportation and is responsible for developing plans

> "for the maintenance of traffic control devices, emergency travel routes to be used in the event of an emergency, placement of barricades as necessary or as directed by the chiefs of the Police and Fire Suppression and Rescue Divisions, direction and control of traffic and coordination with all other agencies supplying common carrier services."

An Emergency Management Committee (EMC) provides staff to support the EOB. Over two dozen City agencies, other governmental agencies and private organizations participate in activities of the EMC. The EMC develops plans and programs and conducts training exercises to promote integrated disaster planning, response and mitigation efforts.

An Emergency Operations Center (EOC) of the EOO provides a centralized coordination facility for emergency response activities. The EOC is located four floors underground and is equipped with vital communications and backup power, food and other supplies necessary to provide for the needs of the EOO emergency response coordinating team for approximately two weeks. A mobile EOC unit is available in the event the primary center is inaccessible or to provide additional disaster response coordination capability. It is comprised of a fleet of vehicles which contain portable offices, communications, self-sustaining power, rest rooms and other resources to enable the mobile EOC unit to operate at any location to which it is sent.

To enhance communications and provide additional communications back-up, the City, as a member of the Operational Area Satellite Information System (OASIS), through the EOO is linked to the Governor's Office of Emergency Services (OES) by satellite. At the time this Element was prepared, Los Angeles was the only city participating in OASIS. OASIS interconnects all of the counties within the State to the OES which in turn is linked to national communications systems.

In the event of a disaster or emergency, the Mayor assumes emergency powers, as defined by law. City agencies follow procedures contained in their emergency plans, under the direction of the Mayor and Chief of Police, pursuant to EOO protocols set forth in the EOO ordinance and plans.

The EOO Master Plan and individual agency "Emergency Response Plans" set forth procedures for City personnel to follow in the event of an emergency. "Annexes" to the Master Plan include hazard-specific plans (*e.g.*, flood), situational contingency plans for known or anticipated events (*e.g.*, annual L.A. Marathon) and pre- and post-event plans (*e.g.*, "Recovery and Reconstruction Plan").

Other interagency coordination. Individual jurisdictions long have cooperated with one another in responding to emergency incidents. At one time emergency response personnel had to remain at their own boundaries, unable to respond to fires or other emergencies across their borders due to territorial requirements. Such territorial limitations were recognized as unacceptable for maintaining public health and safety and resulted in informal and formal aid arrangements between agencies and jurisdictions. These typically enabled the closest available unit to respond to an emergency incident. The agreements usually provided for compensation of the responding jurisdiction for services rendered. Interjurisdictional assistance to assure public safety, protection and other assistance services today generally are in the form of "mutual aid" agreements.

Mutual aid and other agreements provide for voluntary cooperative efforts and for provision or receipt of services and aid to or from other agencies or jurisdictions when local capabilities are exceeded by an emergency event. Through mutual aid agreements, the EOO and individual City agencies coordinate emergency response planning with adjacent cities, the County of Los Angeles, the State, federal agencies and other public and private organizations, such as the Los Angeles Unified School District and the American Red Cross. In addition they share information so as to improve hazard mitigation efforts and coordinate resources for disaster response and recovery. For example, in the event of a disaster, Los Angeles County is required by State law to provide the City with coroner, health, mental health, prosecutorial, court and children's services. The OES is designated by law to provide coordination and State resources to regions or local areas which are declared disaster areas by the Governor. The Federal Emergency Management Agency (FEMA) is designated by federal law to coordinate and provide Federal resources to state and local government relative to disasters declared by the President. To facilitate rapid response to wild fires in brush and forest areas, the U.S. Forest Service has agreements with the County and City fire services for simultaneous dispatch of personnel and equipment to fight fires in designated geographic areas ("Initial Action Zone"). The Public Works Mutual Aid Agreement, conceived by Los Angeles County in the late 1980s, provides for sharing of personnel and public works equipment between signatory cities and counties within the State during times of emergency. In addition, sometimes the City provides a specific service by contract to another jurisdiction. For example, for a set fee, the City provides fire and emergency medical services to the City of San Fernando which is geographically surrounded by Los Angeles.

Following the disastrous Oakland-East Bay Hills fire of 1991 the State legislature directed the OES, in coordination with other State agencies and interested local emergency management agencies, to establish by regulation the Standardized Emergency Management System (SEMS). The SEMS became effective September 1994 (Government Code Section 8607). It is a command management system which is based upon the Incident Command System (ICS).[3] Like ICS, the SEMS is not a physical agency, it is a procedure for integrating emergency response functions. It sets forth a system and framework within which response agencies which utilize the SEMS can function in an integrated fashion, in effect becoming a single response entity. The SEMS outlines a chain of authority (command) for organization of all public emergency response functions within the State. As its name implies, the SEMS provides guidelines for standardization of procedures and approaches to emergency response; facilitation of the flow of information and resources between organizational levels (field, local government, operation area, regional and state); coordination between responding agencies; and rapid mobilization, deployment, use and tracking of resources. Cities and counties are encouraged to utilize the SEMS in order to qualify for State funds for emergency response activities. At the time this Safety Element was under preparation the EOO was reorganizing so as to implement the SEMS for the City of Los Angeles.

In addition to agreements between government entities, private organizations play a key role in disaster planning and response. In particular, the American Red Cross, Salvation Army, churches and other non-profit organizations provide food, shelter, clothing, health care, volunteer labor and other emergency services to disaster victims, in coordination with the governmental agencies. A variety of private sector organizations have been formed to coordinate community emergency preparedness efforts, to heighten public awareness and understanding of the need for disaster preparedness and to encourage private disaster preparedness activities. Los Angeles Unified School District and City park facilities are the designated assembly and coordination locations for emergency sheltering and assistance efforts coordinated by the Red Cross, the State and/or FEMA. In addition, the Red Cross provides interagency emergency response planning and training support.

CALIFORNIA STATE SAFETY ELEMENT REQUIREMENTS

General mandates and guidelines. City and county general plans are required to contain a safety element which addresses natural disaster hazards. This Safety Element fulfills this State requirement. It should be noted that the term "safety" does not mean "police." Safety, in the context of the General Plan law and the subject Safety Element, addresses natural hazards associated with fire, flood, earthquake, landslides and other hazards generally asso-

[3] *For more about the Incident Command System, see Chapter II: Fire and Rescue.*

ciated with or compounded by natural events. State law also indicates that hazardous materials should be addressed by a safety element. In this Element, hazardous materials are addressed primarily in relation to natural disaster hazards, *e.g.*, release of stored chemicals as a result of fire or earthquake. Other elements of the General Plan address other hazardous materials issues.

Local officials have the authority to declare a local emergency and to invoke emergency regulations to facilitate response to the emergency. Planning and preparedness are critical in mitigating the extent of the impacts of a disaster, through pre-disaster abatement, pre-disaster response preparation and post-disaster recovery plans. The State identifies local safety elements as key tools for assisting local jurisdictions in organizing their hazard mitigation, disaster response and recovery efforts.

In 1975, the State mandated that general plans contain safety elements. The general plan law was amended in 1984 to remove seismic elements from the list of required elements and to incorporate seismic provisions within the safety element provisions. The amended law (California Government Code Section 65302.g) requires that a city's general plan contain a

> "safety element for the protection of the community from any unreasonable risks associated with the effects of seismically induced surface rupture, ground shaking, ground failure, tsunami, seiche, and dam failure; slope instability leading to mud slides and landslides; subsidence and other geologic hazards known to the legislative body; flooding; and wild land and urban fires."

These components need not be contained within the same general plan document. Other components may be added, as deemed appropriate by a local jurisdiction. A city within a county may adopt by reference all or part of the county's safety element, providing that the county element is sufficiently detailed to apply to the City.

The intent of the State in requiring mandatory planning was to reduce deaths, injuries, property damage and economic and social dislocation resulting from "natural hazards." A safety element is intended to be the primary vehicle for relating local safety planning to land use planning and decisions.

Jurisdictional infrastructures, such as roads and emergency services, have become increasingly interrelated. Therefore, local jurisdictions are encouraged by the State to coordinate their general plans with neighboring jurisdictions. The Los Angeles County Safety Element includes all of the cities and unincorporated areas within the County and interrelates the critical service systems, evacuation routes, *etc.* for the entire county. The subject Element and its associated graphic exhibits utilize and are consistent with the County Safety Element.

State required mapping and content. Relative to fire and geologic hazards, a safety element is to take into account maps of known seismic and other geologic hazards and to address peak load water supply requirements, minimum road widths (for evacuation purposes) and clearances around structures (for emergency access). For information about seismic and landslide hazards mapping, see Chapter II, "Seismic Events."

Dam failure inundation diagrams are encouraged by the Governor's Office of Planning and Research to be incorporated into a safety element. The diagrams are to show the areas of potential flooding in the event of dam failure. In addition, pursuant to the State Emergency Services Act (Government Code Section 8550), the City Department of Water and Power provides dam failure inundation maps to the State Office of Emergency Services via the County of Los Angeles. These maps are the basis of the County inundation maps which were a resource for preparation of the inundation exhibit which is a part of this Element (Exhibit G).

Landslide hazard identification maps are encouraged by the State Office of Planning and Research to be considered in a safety element. A landslide exhibit is included in the attached exhibits (Exhibit C).

State required consultation. Pursuant to Government Code Section 65302g, staff on January 6, 1994, prior to proceeding with the preparation of the subject element, contacted the State Division of Mines and Geology and the State Office of Emergency Services to advise them that preparation of the City Safety Element was about to commence and to solicit advice concerning plan preparation. Staff was advised by these offices that the County of Los Angeles Safety Element provided research data in its technical appendices, including geologic, seismic, wildfire, critical facilities (*e.g.*, evacuation route) and other exhibits, which adequately covered the City of Los Angeles. They advised that the County reports provided an adequate technical basis and could be utilized by reference for the City's element.

Technical references. The City Planning Department reviewed the County Safety Element and decided that it did not contain sufficient City-oriented information to be adopted as the City's safety element. The background data and information concerning the character of natural hazards and history of natural disasters and events relative to the County and its immediate environs provided excellent technical information. However, it did not provide adequate specific information about the history of disaster mitigation in the City. Further, the goals, objectives, policies and programs contained in the County element generally did not apply to the City. Therefore, the City decided to prepare its own safety element and to use the "Technical Appendix to the Safety Element of the Los Angeles County General Plan: Hazard Reduction in Los Angeles County" as a technical resource and its exhibits as a basis for some of the exhibits contained in the City's element. The County Technical Appendix was prepared by Leighton and Associates, Incorporated in cooperation with Sedway Cooke Associates and William Spangle and Associates, December 1990.

The principal data source for the City Safety Element was the Los Angeles City General Plan Framework 1994 Draft Environmental Impact Report (DEIR). In addition to the County Technical Appendix and Framework DEIR, additional information was secured from City historic records, a variety of informational sources and oral interviews with technical staff of various City and other agencies. The exhibits which accompany the Element were based primarily on the County Technical Appendix exhibits and Framework DEIR exhibits, for which the County Technical Appendix was a resource. The City's Safety Element exhibits include information required by the State. They are comparable to and consistent with the County Safety Element exhibits which were deemed by the State to be in compliance with its requirements.

State required format, implementation and monitoring. In addition to State law, the Governor's Office of Planning and Research issues "General Plan Guidelines." The document provides guidance for preparation of local general plans. The 1990 Guide, under which this Safety Element was prepared, advises that a general plan contain goals, objectives, policies, programs and implementation monitoring. The goals are to be general and abstract, suggesting specific actions for achievement. Objectives are to express intermediate steps for achieving goals. Policies are to guide decision making. Each policy is to have at least one corresponding implementation measure.

Los Angeles was the first city in the State to establish an "Emergency Operations Organization" (EOO). The City, through its EOO has developed integrated operational, contingency and long range plans to address all aspects of potential emergency and disaster situations. Therefore, Los Angeles already goes far beyond the intent of the State general plan law and Governor's guidelines relative to a comprehensive City safety element. In keeping with the national, State and City efforts to streamline emergency operations, including planning, the Safety Element complies with the State's general plan laws without creating a new bureaucratic layer or causing duplication of government work. To this end it identifies only one implementation program, the EOO.

The three Safety Element goals parallel three of the primary phases of disaster planning: hazard mitigation (pre-disaster), emergency response (disaster event) and recovery (post-disaster). For the purposes of this Element, planning and training are incorporated under each of these phases. The three categories identify the three steps needed for urban safety relative to potential natural disasters: (1) pre-disaster mitigation of potential hazards which could cause loss of life and property damage during a disaster, procedures for mitigating disruption, provisions for back-up systems necessary for keeping essential City services and systems operational in the event of a disaster; (2) protection of life and property and provision of temporary assistance to disaster victims during and immediately following a disaster; and (3) post-disaster elimination of disaster-created hazards, re-establishment of private and public services and systems and general recovery.

The policies to achieve Element objectives are administrative. They generally provide broad guidelines for program formulation. Given the complexity of Los Angeles City government, often more than one EOO program emanates from a policy or more than one policy guides program formulation. Every policy contained herein is implemented by at least one EOO program or protocol, *i.e.*, a program which is administered by the EOO or one or more of its member City agencies. The broadly stated programs of this element describe the type of EOO programs which implement each policy of the Safety Element.

The Element complies with State law by providing a contextual framework and overview of the City's natural hazards, hazard mitigation and emergency response operations. It is not as comprehensive as the EOO establishing ordinance, Master Plan, Master Plan Annexes and associated plans insofar as the Element is informational rather than operational document and generally does not address social and police issues (*e.g.*, crowd control and riots). The EOO Master Plan and its related documents provide comprehensive (including police) operational protocols and plans. They are reviewed and approved not only by the EOO Board but by the Mayor and City Council and, therefore, are City policy. More importantly, they are operational documents, not just planning documents, and they are updated continuously.

The Safety Element is listed as a program of the EOO "Recovery and Reconstruction Plan" (aka "annex"). Therefore, the EOO's periodic monitoring of that annex will include a review of the Safety Element for purposes of recommending revisions. The Safety Element format, programs and monitoring are in compliance with State law and state general plan guidelines.

ELEMENT SCOPE

Prior General Plan elements. The Safety Element is less complex than the former safety, seismic and fire elements of the General Plan which were prepared in the 1970s. It simplifies goals and policies and identifies program categories. It generally does not contain standards and technical guidelines because these already are contained in City codes and administrative procedures which implement the EOO plans.

Jurisdiction. Element implementation involves only those programs which are within the authority and responsibility of the City of Los Angeles.

Police. The Element addresses only natural hazard issues. Therefore it does not address police matters, except in relation to natural disasters, *e.g.*, traffic safety during or following a disaster.

Wind. No wind hazard section is contained in the Element. Generally the most severe wind conditions come in the autumn when the dry Santa Ana or "devil" winds contribute to wild land (brush fire) conditions or cause localized minor damage. These winds rarely reach a velocity of more than 75 miles per hour. Wind hazards, such as tornadoes, are rare and in recent history have resulted in relatively minor, localized impact. The most damaging tornado recorded in Los Angeles occurred in 1983. It traveled several miles, moving north from South Central Los Angeles and the vicinity of the Convention Center in the Central City. Vehicles were turned over and many homes and other structures, including the Convention Center, were damaged. There is no record of a hurricane having struck the City in modern times. The City does not have large areas of flat agricultural or vacant lands which necessitate wind barrier protection. The anchoring of structures pursuant to seismic safety requirements assumes anchoring needed for wind considerations.

Assumptions. The City's EOO programs, including the subject Element, emphasize mitigation of potential hazard impacts, rather than avoidance through land use prohibitions, except as required by State flood and seismic regulations. This is because, by and large, the City is a built city and damage due to disasters such as fire, seismic event or hazardous materials release could occur anywhere in the city regardless of distance from identified major earthquake fault rupture zones, forested areas or concentrations of hazardous materials. The assumption is that hazard mitigation strategies, such as building design, and pre-event training and planning can reduce damage, disruption, injury and costs resulting from natural disasters and will facilitate more rapid short and long term recovery following a disaster.

CHAPTER II - EXISTING CONDITIONS, HAZARD ISSUES AND MITIGATION HISTORY

Much of the City of Los Angeles is built within old flood plains and mountains or adjacent to the Pacific Ocean. The population is concentrated within urban centers which are interspersed by low density residential neighborhoods. Most of the flat lands of the City have been developed with some land use. Remaining open space tends to be concentrated within flood plains or along steep hillside and drainage water courses which typically have been designated as public park land, recreational, flood control or low intensity uses, consistent with State law. Vulnerability to fire and flood has increased as development has encroached into remaining open space areas. Concentration of development and infrastructure has increased the vulnerability of greater numbers of people, businesses and facilities to seismic, fire and flood events while at the same time providing greater resources for responding to such events.

When a catastrophic natural disaster strikes, it may trigger secondary events. An earthquake may trigger a landslide or cause rupture of gas mains or hazardous materials enclosures. Disruption of gas mains could contribute to or cause fires. If winds are present, fires could become wild fires. Fires can denude hillsides and, thereby, exacerbate potential flood hazard and inundation conditions. For purposes of evaluating natural hazards addressed by this Safety Element, the following sections provide a brief history of the measures taken to mitigate individual natural hazards in Los Angeles.

FIRE AND RESCUE[4]

Fire was the first "natural" hazard to be addressed by El Pueblo de Los Angeles which was founded in 1781. The hot, arid climate, especially during the summer and fall, dried out vegetation. Dry brush was prone to fires caused by lightning strikes and spontaneous combustion. Nature adjusted to this phenomenon by making some of the native chaparral (vegetation) dependent on fires for regeneration. Their seed cases opening only when heated by fire. New sources of fire came with the advent of human habitation. By the early 1800s Los Angeles was an agricultural community with a small population. Buildings generally were constructed of adobe and tile. Individual properties experienced fires such as hay mounds igniting spontaneously, roofs being set afire by sparks from cooking stoves or fires due to carelessness. The primary fire hazard was storage of large quantities of hay. No fire bells or alarms existed. Instead someone would shoot a gun in the air repeatedly to attract assistance and volunteers formed leather bucket brigades to douse fires. As the City grew and buildings were established in close proximity to each other, entire blocks could burn in a matter of hours due to the lack of adequate water storage and delivery systems. Given these potentially catastrophic hazards it is not surprising that some of the earliest City building regulations addressed fire hazards.

Fire Department established. In 1869, officials and interested men met at Billy Buffum's Saloon and formed the City's first informal volunteer fire department. They convinced the City Council to levy fines on alleged arsonists so as to raise money for equipment. Because the levies also were used to drive unwanted elements, such as prostitutes and immigrants, from the City, not much money was raised. After the disastrous Chicago fire of 1871, the Volunteer Fire Department was recognized formally and the City Council allocated money for construction of a fire house. Water delivery was a major problem in the early years due to feuds with the local water company, lack of water supplies and lack of an integrated water system. The volunteers pleaded for pumping and other equipment but the City Council was reluctant to expend money because fires were deemed an inconsequential problem. To secure equipment, the volunteers solicited donations. In 1872 they purchased the City's first piece of modern fire fighting equipment, an Amoskeag steam pump. The City's first paid fire fighting employee was an engineer hired by the City Council at $100 a month to operate the pump and

[4] *A primary source used in in the preparation of this Element relative to Fire Department history, especially early history, was Paul C. Ditzel's* L.A.F.D. Centennial Edition, *Jostens Printing and Publishing Co., Visalia, California, 1986.*

help manage the firehouse. The heavy pump had to be pulled by the volunteers to fires because the Council refused to allocate funds to purchase horses. Sometimes the pump became bogged down in sand and never made it to a fire site. In 1874 the volunteers became so upset over the Council's failure to buy horses that they threatened to quit. This prompted another meeting at Buffum's. After the meeting, town leaders convinced the City Council to turn over the new fire station to the volunteers and to provide horses for the pumper. But it was not until 1875 that funds were appropriated for two horses. In that year, the volunteers began using chemicals (carbon dioxide) to help extinguish fires. By 1881 demand for fire fighting still was small. Of the 33 fire calls, 15 were false alarms and only $950 was sustained in fire damage. Sometimes months went by when no fire calls were received. Major fires were rare but the potential for major disaster soon became apparent.

In September 1883 the Los Angeles area experienced the worst brush fire it had known to that date. It was centered in the Coldwater Canyon area, eight miles west of the city limits. It burned for three days, destroying acres of watershed as well as cottages, barns, farmhouses, entire ranches, a bee farm, haystacks and crops. Although County personnel fought the fire, the City Council realized the City was vulnerable to a similar catastrophe. Subsequently, it took steps to improve the fire protection system, including a review of ways to improve the fire alarm system which still was comprised of people shooting guns in the air and ringing church and other bells. The old firehouse was replaced in 1884 by a new Plaza Firehouse, which still stands in the El Pueblo de Los Angeles State Historic Park near the civic center. In 1885, instead of constructing an alarm bell system, the Council voted to establish a City Fire Department with paid fire fighters.

The Department was established on February 1, 1886. Walter S. Moore, who had served three non-consecutive terms as volunteer fire chief and as president of the City Council for a term, was hired at $125 per month as the first salaried Chief Engineer. Thirty fire fighters, most of them former volunteers, were hired to man four leased firehouses. In addition, volunteer units were retained in the less populated areas outside the central city, including the San Fernando Valley. In 1898 a $150,000 bond issue was approved for purchase of the first city-owned fire station sites, construction of 12 stations and establishment of a more efficient alarm system using new telephone and telegraph technology. Engine Company No. 1, the first City-owned station, became operational in 1887 at the site of what today is the Fire Department's supply and maintenance facility. A unique feature of the station was a hanging harness developed by one of the firemen. Horses were trained to walk under the harness upon hearing the fire bell so the harness could be quickly lowered and strapped onto them. This time saving innovation was adopted by stations across the nation.

From the beginning the Department was an innovative, progressive agency which sought to secure the latest equipment, utilize the latest techniques and to develop better methods for fire fighting and prevention. The 1920s was a period in which the Fire Department grew and developed into a premier fire fighting force. It explored and experimented with new techniques and received considerable public support for purchase of modern equipment and expansion of its stations and personnel. By 1921 the Department had become fully motorized. Recognizing that costly property loses were occurring due to smoke, falling debris and water damage, the Department experimented with salvage techniques. In 1923 it became the first major fire department in the nation to operate its own fleet of salvage rigs. Salvage teams were assigned throughout the City. At fire sites they covered furniture and valuables with tarpaulins while the fire fighters fought the fires. This tactic significantly reduced property damage and improved insurance ratings for the City. A Demolition Corps of personnel who were trained in handling explosives was established for such duties as dynamiting fire or flood damaged structures, preparing fire breaks and combating gas fires. Around 1924 the Department became the first major fire agency in the nation to equip all of its vehicles with two-way radios.

Fire Department expansion almost halted during the period of the Great Depression due to a lack of monetary resources. During the early 1940s, training and procedural changes reflected war concerns, including response to possible air raid attacks. A special Mountain Patrol was established to monitor potential targets of anticipated incendiary bombs.

After World War II the Department expanded dramatically in response to a commercial, industrial and population boom. Passage of a $4.5 million bond issue in 1947 enabled the construction or upgrading of 35 stations and purchase of new, modern apparatus. Upgrading of its services earned the Department its first national Board of Fire Underwriters "Class I" rating (1947).

Fire prevention. Fire prevention long has been recognized as the best method for reducing fire incidence and devastation. As the Fire Department became more organized and better accepted, the City adopted fire regulations and authorized fire fighters, police and other officials to enforce them. Increasingly comprehensive ordinances were passed to regulate building design, materials and occupancies so as to better contain fires and reduce fire hazards.

The first regulations applied to Fire Districts which were established in 1869 in the most densely developed sections of the City. By 1874 the amount of hay, gun powder and kerosene which could be stored in buildings was regulated, outside walls and roofs were required to be made of noncombustible material and stoves to be surrounded by masonry. In the 1880s concern regarding spread of fire and loss of life resulted in requirements for separate exits for large assembly halls, fire walls between adjoining buildings, exit aisles and swinging doors. In some districts, such as what is now the Central City, wooden structures were prohibited and masonry structures were required. Wood remained the most common construction material for buildings outside of the downtown fire districts. In 1907 water connections were mandated for new and existing homes. With the advent of electrical wiring, fire hazards increased, leading to the establishment of electrical safety codes.

Around the turn of the century, insurance companies played a significant role in the improvement of fire standards throughout the nation. Facing high costs from poorly managed fire systems, the fire underwriters joined together in an association which established fire rating systems to assess efficiency and effectiveness of local fire hazard mitigation and fire fighting agencies. Insurance rates were established accordingly. Cities could lower their fire insurance rates if they improved their hazard mitigation and fire fighting systems. This economic incentive spurred nationwide interest in fire prevention and suppression and continues to do so to this day.

In 1916 a Fire Prevention Bureau was established to carry the message of prevention to the general public, encourage voluntary hazard prevention measures, enforce hazard mitigation ordinances and improve prevention regulations and methods. The Bureau quickly inaugurated its first public information program. It was aimed at the general public and especially at children because fires set by children playing with matches was one of the major causes of fires. Public education was recognized as an important fire prevention tool. Programs, like firemen's musters (skills demonstrations) were designed to interest the public in fire prevention and to recruit young men into the volunteer fire service. Firemen visited schools to demonstrate their equipment and techniques and to present a fire prevention message. By 1929 Los Angeles boasted an average $1.05 per capita loss due to fire incidents, compared to the $2.10 national average. This was due in large part to the Department's aggressive efforts to improve its own resources, techniques, equipment and response as well to the upgrading of fire prevention and suppression regulations, strengthening of enforcement and improving the public's fire prevention awareness.

In 1942 a Junior Fire Department was established in conjunction with the city schools. Not only did it inculcate good fire prevention awareness but it provided a sort of Little League for fire service by providing a career development program. School and community fire prevention programs to this day are an important means of encouraging the public to exercise fire prevention in their daily lives.

Fire prevention measures often were adopted following fires which resulted in loss of life or significant property loss so as to prevent similar occurrences in the future. Sometimes it took more than one tragic event to trigger public support for changes. This was due to conflicts between life safety issues and costs to property owners who would be required to implement safety features. For example, as early as 1912, a fire in the St. George Hotel in the downtown raised the issue of the danger of open stairwells in spreading fires. However, no action was taken. In 1928 open stairwells contributed to a fire in the Ponet Square Hotel in the Central City area.

In 1952 seven people were killed in a second St. George Hotel fire. Following this fire, *The Los Angeles Daily News* ran an exposé which revealed that 248 hotels and apartment buildings (10,000 units) had fire violations and open stairwells which made them firetraps. Nevertheless, a proposed stair enclosure ordinance was not adopted. It took the tragic second Ponet Square Hotel fire of 1970, in which 19 residents lost their lives, to provide the impetus for passage of an ordinance. The Ponet Square Ordinance included requirements for stair shaft enclosures, self-closing doors and one-hour fire doors. It applied retroactively to pre-1943 structures of three or more stories in height. A four-year grace period was allowed for compliance. Over 1,200 of the 1,487 buildings affected by the retrofitting provisions were located in the older Central City area.

A major multi-casualty fire occurred in the Stratford Apartments (Westlake community) in 1973. It took the lives of 25 of the 120 tenants, including nine children. The Stratford was a pre-1943 building which had not been retrofitted. Following the fire, the Ponet Square Ordinance compliance grace period was rescinded. The 1983 Dorothy Mae Apartments fire resulted in the loss of 25 civilian lives in a building which had been retrofitted to comply with the Ponet Square ordinance. Most victims lost their lives in the hallways at stairwell exits due to flash over situations. To prevent similar tragedies, a retroactive ordinance was adopted for pre-1943 apartment and hotel buildings of three or more stories. It required automatic sprinklers in common areas and inside entry doors to each residential unit and mandated installation of fire alarm systems.

The Department has not waited for fires to happen. It has been aggressive in researching and evaluating fires. Operation School Burning was instituted by the Department in 1958 following the Chicago Our Lady of the Angeles parochial school fire which killed 95 children and teachers. The program utilized a vacated school facility to monitor scientifically the propagation and spread of fires and methodologies for preventing, suppressing and containing fires and saving people. From this program came supervised school fire drills to train students and teachers to respond appropriately and without panic to a fire situation. In addition, new regulations were developed to make schools safer.

A similar program was utilized in 1977-78 to evaluate house fires and to develop and field test prevention and suppression measures. It demonstrated the effectiveness of early warning, sprinkler systems and smoke detectors in homes and dramatically changed available information about the time/temperature curve for fire development. Findings were utilized by private industry in product development.

Fire prevention and enforcement measures account for a continuing reduction in deaths and injuries associated with fires related to structures. For example in 1983-4 the Fire Department responded to 5,620 structural fires. In 1992-3 it responded to 4,010 structural fires even though the City's population had increased by 17% (500,000 people), new construction had increased substantially and a greater intensity of development had taken place, *e.g.*, multi-story and high rise buildings had replaced low density structures.

Training. Unlike fire agencies in many other jurisdictions, all Fire Department emergency personnel, including fire fighters, inspectors and an increasing number of emergency medical personnel, are trained fire fighters and all are given emergency medical training. This enables an efficient mobilization in event of major emergencies and has resulted in a department in which fire fighters are multi-skilled. Fire fighters receive on-going skills training to familiarize them with new techniques and equipment and to refresh their skills.

The Department long has been known for its innovative leadership in the field of fire fighting techniques and strategies. In the early days, firemen responded in an ad hoc fashion to fire incidents. They used their muscle, agility and quick wits to assess and respond to a situation, often operating independently of each other. The ad hoc approach to fire fighting was inefficient and sometimes resulted in injury to firemen. To improve efficiency, safety and effectiveness the Department established a unique Fire College. The program included classroom training as well as exercises under simulated emergency and fire conditions. It was the first such educational program in the nation. Instructors were required to have at least seven years of fire fighting experience and a teaching credential from the University of California at Los Angeles. The first class graduated in 1925. The Fire College transformed the Department into one of the most professional in the nation and was credited with a significant reduction in property losses and loss of life due to fire. It was so successful that in 1931 the Federal Board of Vocational Education incorporated the College's curriculum into a standard curriculum for fire personnel. Fire College instructors were hired by the International Association of Fire Chiefs and National Board of Fire Underwriters to help other departments establish similar training programs.

In 1957 the Emergency Operational Procedures Manual was developed to provide coordinated ground and air procedures for fighting brush fires. The manual was the precursor of the Incident Command System which provides coordinated procedures for multi-unit response to emergency events. Exercises were conducted to assure that personnel were familiar with the procedures, thereby increasing efficiency and effectiveness.

Coordination/mutual assistance. Because the City surrounds other cities, *e.g.*, Beverly Hills and West Hollywood, and adjoins other cities as well as county, state and federally controlled lands, it has joined in a variety of agreements with other jurisdictions for cooperative response and management of fires and other emergency incidents. Containment and suppression of a fire within an adjoining jurisdiction protects the City from encroachment and damage from the fire, thereby protecting the population as a whole. Most of the agreements are voluntary. Services are accepted and rendered at the discretion of the respective jurisdictions, depending upon factors such as availability of personnel and equipment. Under such agreements, usually the nearest fire units, regardless of jurisdictional boundaries, respond to fire or emergency medical calls. For example, since 1952 the Department has participated in a memorandum of understanding with the U.S. Forestry Service to render "all reasonable assistance" in suppressing fires along or near the National Forest boundary. It participates in automatic response agreements with the County and adjoining cities of Beverly Hills, Burbank, El Segundo and Santa Monica for fires within specific geographic areas of each jurisdiction and in contract agreements to provide services to the City of San Fernando and the community of Bell Canyon (in Ventura County). Under mutual aid agreements, personnel and equipment sometimes are loaned to jurisdictions experiencing major incidents which exceed their resources. For example, when an area experiences major brush fires, crews and equipment sometimes are sent from not only other California jurisdictions but other states as well, through agreements coordinated by the Governor's Office of Emergency Services or the Federal Emergency Management Agency. In recent years, City fire fighters have assisted in suppression of brush fires in the immediate region and as far away as Mammoth Lakes in the High Sierras and Mt. Palomar in San Diego County.

When a major disaster strikes, local, state, federal and private agencies respond under mutual aid agreements and federal, state and local disaster response procedures. The City's Emergency Operations Organization is the primary City organization under which City agencies join together in emergency preparation, response and recovery planning. In addition, the fire and police departments and other emergency response personnel participate with like agencies in other jurisdictions in training exercises and network coordination. Following the Watts civil disturbance in 1965 the Fire Department developed a task force procedure for more efficient deployment of personnel and equipment in response to emergencies. Civil disturbances and increased violence have resulted in cooperative procedures between state and local law enforcement agencies and the Fire Department to protect fire fighting and rescue personnel.

Coordination sometimes has been hampered by a lack of compatible communications systems, utilization of different terms for agency functions and a confusing variety of local agency organizational structures. These factors hampered communications and sharing of resources to fight a series of devastating fires in the Southern California region during 1970. The experience resulted in establishment by the U.S. Forestry Service of a partnership of local, state and federal fire agencies to develop improved coordination for fire suppression management and emergency response. The partnership evolved into the Fire Resources of Southern California Organized for Potential Emergencies (FIRESCOPE) program. FIRESCOPE[5] developed the Incident Command

[5] *When FIRESCOPE became state wide, the word 'Southern' subsequently was dropped but the acronym 'FIRESCOPE' was retained.*

System (ICS) and Multi-Agency Coordination System (MACS) which were designed to improve multi-agency response to multi-hazard events, including earthquakes, floods and fires. The Los Angeles City Fire Department was a leader in developing these programs and one of the first to make them operational. The programs established plans and procedures for improved interagency coordination, including common terminology, organizational structures (chain of command) and response procedures and for compatible communications (*e.g.*, radio frequencies) and equipment systems (*e.g.*, hose connections). The goal was to make agency personnel and equipment readily interchangeable within and between jurisdictions and command levels so as to facilitate effective deployment and efficient utilization of limited resources between federal, state, regional, district and local agencies and operational levels. When incidents exceed or are anticipated to exceed the resources at a particular response level, assistance is requested from the next level which in turn evaluates the needs and assembles and allocates personnel and other resources. The ICS and MACS procedures were incorporated into the City's fire fighting program where they were tested in mock and real situations. The State's Standardized Emergency Management System (SEMS) regulations of 1994 was patterned in part after the ICS and MACS programs in response to the Oakland-Eastbay fire in northern California. The SEMS encourages compatibility between all emergency agencies operating within the State. The agreements described above are but a few of the cooperative agreements in which the Fire Department is a party.

Brush fires. Brush fires continue to be a major threat to life and property throughout the region due to unique fuel, terrain and climatic conditions. The hazard is especially great when the dry "Santa Ana" winds arrive, usually in the fall and winter seasons. The desert blown Santa Anas turn vegetation to tinder and spread localized fires quickly. A brush clearance program was instituted in 1920 using paid civilians to clear vacant lots of debris and rubbish. The program significantly reduced brush fires. In 1924 a civilian Mountain Fire Patrol was established to improve fire safety in hillside areas. The Patrol counseled private property owners in fire prevention and encouraged them to maintain burlap bags and other fire fighting material to protect their homes which often were distant from fire stations or were not served by adequate roads. Boxes of fire fighting tools were placed at strategic locations along Mulholland Drive and fire breaks, fire trails and fire roads were maintained to slow movement of fires and provide access for fire fighters. However, the fire breaks proved ineffective with major fires. Wind conditions, including those generated by a fire, could carry burning embers and materials far beyond fire breaks. In 1958 the City banned incinerator and open burning to reduce fire hazards and improve air quality. The ban resulted in the lowest incidence of fires in 14 years.

To date, the 1961 Bel Air fire storm in the Santa Monica Mountains is ranked as the City's most costly brush fire. The 50 mile an hour Santa Ana winds, combined with fire-generated winds, carried burning debris and set new fires far from the main front. Within the first six hours, before defensive procedures became effective, 484 homes and other structures were destroyed. The fire lasted two days, destroyed over 500 structures and burned 6,090 acres of watershed within a 19-mile perimeter. Even with this loss, 78% of all the homes within the perimeter were saved. A direct result of the fire was the phasing out of the Mountain Fire Patrol, rebuilding the two existing fire stations and constructing two new stations along Mulholland Drive, the road which runs along the ridge of the Santa Monica Mountains. In addition, the Mountain Fire District and Buffer Zone boundaries were expanded to include a greater area and a Department Brush Clearance Unit was established to enforce brush clearance regulations in the Districts and Zones. The Public Works Department's Bureau of Street Maintenance took over the responsibility of enforcing brush clearance on vacant lots within other areas of the City.

Devastating brush fires have resulted in establishment of more fire stations and facilities in hillside areas and in more stringent requirements for fire hydrant installation, hillside brush clearance, fire access road systems, home sprinklers, fire resistant construction and landscaping materials, and development of improved fire fighting strategies and equipment. In 1962 the Department acquired its first helicopter with water dropping capability. Subsequently, air craft became important equipment for fighting brush fires. They were used for dropping water and chemicals on targeted fire areas. Flammable roofs long had been identified by fire agencies as major contributors to property damage and the spreading of fire storms in developed areas near brush lands. In 1970, following the Chatsworth fire in which 113 homes were damaged or destroyed, the City required that new homes in Mountain Fire Districts treat combustible roof materials so as to make them more resistant to fire. Following the devastating December 1989 Sesnon (Granada Hills) fire which destroyed or damaged 30 dwellings, combustible roofing material was banned from use in construction of new homes in Mountain Fire Districts.

Between October 25 and November 10, 1993 an unprecedented series of 22 devastating wild fires occurred in the six county Southern California region (from Ventura to San Diego County). The fires were caused by arson (12 fires), arcing power lines (6), campfires (2) and undetermined sources and were fanned by Santa Ana winds and fueled by a combination of dead undergrowth resulting from a seven-year drought and heavy new growth caused by recent rains. The fires burned 197,277 acres, destroyed over 1,170 structures and killed three people. They were battled by a force of 9,476 fire fighting personnel from 458 agencies from around the nation. The last and largest of the fires was in the Topanga-Malibu area (November 2-7). The fire burned 18,000 acres, destroyed 384 structures and killed three civilians. Fire fighters were shifted by the FIRESCOPE center in Riverside County from other fire sites to Malibu-Topanga and placed under the command of the Los Angeles County Fire Department. The largest commitment of fire personnel in fire fighting history, 7,136 fire fighters, were involved in battling the Topanga portion of the fire and a total of over 9,000 personnel battled both segments. The fire was an extremely dangerous, rapidly changing, fast moving fire. Fire fighting was hampered by steep hillside terrain, narrow mountain roads, falling debris dislodged by the fire and shifting winds which sent flames up to 200 feet in the air and carried burning embers which ignited new fires. Resources were deployed to protect structures and to contain and eventually suppress the fire. Fixed wing and helicopter aircraft were used to battle fires.

The 22 fires, especially the Topanga-Malibu fire, successfully tested FIRESCOPE. Different agencies interacted and combined into a single force under a unified command system as planned by the FIRESCOPE protocols. The fires also tested the processes and procedures of individual agencies to combat and manage major fires and proved the effectiveness of the City's hillside brush clearance law. Clearance of brush within 100 feet of structures in Mountain Fire Districts not only protected the structures but enabled fire fighters to battle fires without having to stand in fuel (brush). Following the fires, the Governor's Office of Emergency Services convened a survey team to review all of the fires and recommend additional procedures and measures to improve response and coordination. A direct result of the Topanga-Malibu fire was the signing of a cooperative agreement for use of planes ("Super Scoopers") which could scoop water from the ocean and drop it on brush fires. The Super Scooper agreement marked the first time that federal, state, county and a city had joined in a cooperative agreement with another nation (Canada) and a private manufacturer to test new equipment in the field as a means of exploring new fire fighting tools. Another direct result of the fire was the Department's decision to secure syphon ejectors, pumps and other equipment to enable utilization of water from private swimming pools for fire fighting.

High rise and complex structural fires. Improved building construction engineering, materials and mechanisms made possible construction of increasingly taller buildings. Lighter materials, such as asbestos was used instead of brick for fire proofing. The first four-story wood frame building was constructed in Los Angeles in 1882. By 1888 seven story buildings with brick bearing walls were permitted and fire escapes were required for buildings four stories or more in height. With the advent of elevators and minimal masonry reinforcement, the City in 1903 allowed the construction of its first 13-story office building. In 1905 the fire escape ordinance was made retroactive and enforcement was delegated to the Building Department. Subsequently, water connections were required in new multi-story buildings to facilitate fire fighting. In 1910 the height limit was set at 150 feet (13 stories) for steel frame office buildings, the maximum possible under then available engineering techniques, and five stories for residential buildings, including hotels. After building technological advances enabled construction of taller buildings, the height limit was retained to assure that the proposed City Hall would be the City's tallest building. City Hall was dedicated in 1928 and at 452 feet in height (over 28 stories) it remained the tallest building until the 1957 floor area ratio ordinance replaced the height ordinance. The 1957 ordinance allowed unlimited height with a maximum floor area in order to encourage provision of open space and more imaginative building design. In 1962 the 32-story Occidental Tower (later TransAmerica Building) was constructed in the Central City community. It became the first building to exceed the height of City Hall. Hundreds of high rise buildings have since been constructed in the City. This has necessitated entirely new techniques for fire mitigation, suppression and rescue.

In 1964 Operation High Rise was instituted. It used empty buildings to study the propagation, effects and spread of fires and to develop systematic response and suppression procedures for high rise fires. Procedures developed by this unique program and subsequent programs have been used by emergency response agencies throughout the world. The first significant local test of Operation High Rise was in 1968 for a fire in the 9-story U.S. Borax and Chemical Corporation building in the Westlake area. Heat activated elevator buttons caused elevators to be called to and to remain at the fire involved floor, resulting in the death of one fire fighter. Emergency alarm systems failed to work and hand held walkie talkies proved ineffective inside the building. Out of this tragedy came new building construction requirements and fire fighting procedures, including banning of heat activated elevator buttons by Los Angeles and establishment of a new Department procedure requiring fire fighters to use stairs instead of elevators to gain access to a fire involved floor. The first major high rise fire in the nation, the One New York Plaza fire of 1970, triggered a national review of hazards associated with high rise buildings. The California State Legislature in 1974 adopted high rise fire safety regulations which included requirements for automatic sprinkler systems in any new buildings which were 75 or more feet in height.

Revised procedures were successfully used in the 1971 Westwood Center Building (Glendon Avenue, Westwood community) fire. The Department quickly contained the fire and suppressed it within half an hour. In 1976 the new Incident Command System (ICS) was instituted. It was designed to improve operations and coordinate fire suppression resources. Its first major test was the 1976 fire on the 20th floor of the Occidental Tower building. The success of ICS resulted in adoption of the ICS methodology by other emergency response agencies around the world.

The 1979 fire on the 11th floor of the Bunker Hill West Tower (Hope and Third Streets, Central City) was the City's first major fire in a residential high rise building. Residents were phoned and urged to remain in their rooms so that opening of doors would not spread the fire and so that residents would not become victims of smoke inhalation. One couple died when they were literally blown off a balcony ledge when the fire burned from the open room across the hall, through the door to their unit, causing a blast of heated air. Following this tragedy, rescue procedures were improved and, in 1980, smoke detectors were required in all new residential high rise buildings and any high rise buildings which were issued remodeling permits.

In 1984 the Department's improved ICS procedures were successfully used in responding to the 12-story Fickett Towers (Van Nuys community) senior citizen building fire. The fire was knocked down in 71 minutes and all 230 of the elderly and infirm tenants were successfully evacuated.

The most materially damaging high rise fire in City history occurred in 1988 in the 62-story First Interstate Bank Building fire (Wilshire Boulevard at Hope Street, Central City) which claimed the life of one civilian. The fire began on the 12th floor and moved upwards to the 16th floor before it was contained and suppressed. Following the Interstate fire, the City Council required fire sprinklers in the 363 existing commercial and office buildings constructed before the State sprinkler regulations became effective. The fire also underscored to private industry the need for private back-up systems and facilities to enable continuance of business operations following a fire.

One of the most complex and difficult fires ever fought by the Department was the 1986 Central Library fire (5th Street at Grand Avenue, Central City). The open book stacks, narrow corridors, circuitous stairways, interference of the thick walls with the walkie-talkies, lack of windows and ventilation, dense smoke, intense heat (estimated as high as 2500 degrees in some areas), limited access and fire fighter exhaustion due to heat and exertion made the fire difficult to attack. Extensive pre-planning for a potential fire in the historic structure resulted in an orderly evacuation of library staff and patrons and invaluable familiarity of the fire commanders with the building and its unique fire suppression demands. Salvage units quickly instituted procedures to protect the 1.2 million books and documents from smoke and water damage. Ingenious methods were devised to direct smoke from the building and relay fire fighters in and out of the fire areas. After seven hours and thirty-eight minutes the fire was brought under control. It took another five days to mop up the hot spots and for the building to cool down. The 350 fire fighters saved over a million books. Only 350,000 books were fire or water damaged and only 4% of the $500 million value of the structure was lost.

Harbor and airport emergencies. With the annexation of San Pedro and Wilmington in 1909, including property which would become the future Port of Los Angeles, the Department began to develop capabilities for fighting dock and other harbor fires. Two private tugs for ocean vessel and pier fire fighting were replaced in 1916 by a motor launch fire boat and two steam pumpers on a barge. In 1919 the City's first fire fighting vessel was commissioned. A subsequent 1924 bond issue enabled the construction of one of the world's most powerful fireboats. Its "guns" could deliver 10,200 gallons of water per minute to douse waterfront and harbor fires and it had a unique stationary tower which could be extended to 44 feet above the water line. Three more fire boats were added in 1928. In the 1960s, self-contained underwater breathing apparatus equipment enabled more effective response to underwater fires, spills and other emergency incidents in the Port. To facilitate response, the Department has entered into cooperative arrangements with federal, state, county and the adjoining Port of Long Beach for response to fires, hazardous materials spills and other emergencies in the harbor area.

Airport expansion resulted in the establishment of fire stations at the Los Angeles International (LAX) and Van Nuys airports in 1956. As with the harbor operations, special equipment, tactics and training were instituted to prevent, suppress and contain fires and to rescue potential victims. The first major air crash took place in 1978 when a Continental Airlines DC-10 crashed on take-off at LAX. LAX Fire personnel quickly suppressed the blaze and saved the lives of all but three of the 198 passengers and crew. Due to the quick response, the emergency was over in less than six minutes. Today both the port and airports have on-site fire fighting operations and special equipment designed for the unique needs of those facilities.

Arson fires. Arson is a major cause of fire, averaging 10 incidents per day in 1994-95 with an estimated $23 million property loss (18% of the total loss due to all fires). Arson first was recognized as a major issue in 1887 when a spate of arson fires associated with anti-Chinese civil unrest in Los Angeles caused San Francisco insurance companies to cancel policies for properties in the old Chinatown area (roughly from what is now Union Station to the El Pueblo de Los Angeles Plaza). In 1918 the Arson Bureau was established to investigate suspicious fires. The squad was so effective in identifying and bringing arsonists to conviction during the Prohibition era (1920-35) that during the Depression (1927-37) Los Angeles was not plagued by the rash of set fires which was experienced by many other jurisdictions. Arson investigations also led to a better understanding of the causes and propagation of fires and, thereby, assisted and continues to assist in the development of better prevention measures. By 1978 arson had become the fastest growing crime in the United States. To combat the crime, federal agencies joined with local agencies to establish task forces. In Los Angeles the Arson Suppression Task Force consists of representatives from federal agencies, the Fire Department and the Police Department. Arson Section investigations have resulted in a high rate of arrests and convictions, including convictions of the Dorothy Mae and Ponet Square arsonists. Of 148 arson related cases involving adults which were sent to the County District Attorney in 1991-92, 109 cases resulted in commitment of arsonists to imprisonment or mental health facilities or placement under supervised probation.

Hazardous materials mitigation and response. See Hazardous Materials section.

Rescue/medical. Rescue and provision of medical care to victims of fires always has been an important function of the Department. A Rescue Squad began operating in 1922 to provide breathing apparatus and to attend to fire fighters at fire scenes. In 1930 a fleet of six ambulances was purchased to transport injured firemen to hospitals. The service soon was expanded to serve civilian fire victims. By 1957 the fleet included Department ambulances and ambulances operated by private companies. The first paramedic ambulance service was established in 1970. In that year, other City operated ambulances and their crews were transferred to the Fire Department by executive order of Mayor Sam Yorty. The Department reorganized the service and reassigned ambulances and crews to all areas of the City so as to facilitate efficient response. By 1973 all contract services with private ambulance companies had been phased out and the Department had assumed authority over all first care (response) medical service within the City. The operation was upgraded and became the Bureau of Emergency Medical Services. All of the Department's fire fighting personnel are trained in emergency medical skills so as to enable any fire fighting team to respond to an emergency medical call. By the 1990s more calls were received for medical services than for fire fighting services, *e.g.*, approximately 77 percent of the all calls received in 1993-94 were for medical services.

Following the collapse in 1963 of the Baldwin Hills Dam, the Department's new helicopter was used to rescue stranded and endangered victims. The success of the helicopter operation resulted in purchase of a fleet of helicopters. Following the 1992 drowning of a teenage boy in the Los Angeles River channel, the Los Angeles River Rescue Task Force program was established in cooperation with the Army Corps of Engineers and the County of Los Angeles to develop strategies for rescuing people who might become trapped in the over 400 miles of the flood control channels which exist within the City.

The Department has been called upon to respond to several major earthquake related emergencies beginning with the 1933 Long Beach quake. Following the 1971 San Fernando (aka Sylmar) earthquake the Department developed an Earthquake Response Plan which was utilized during the 1994 Northridge quake. The Department and other emergency professionals also evaluate response of other jurisdictions to major emergencies in other cities, states and nations so as to assess how to better prepare for local emergencies. Following the 1985 Mexico City and 1987 Whittier earthquakes, the City recognized that its personnel alone were insufficient to provide all assistance needed during and following a major disaster. To address this issue a Disaster Preparedness Division was established within the Fire Department to train City and private sector personnel in disaster response techniques and procedures. One of the programs is the Community Emergency Response Program (CERT) which trains volunteer community, business and City employee representatives in earthquake awareness, disaster fire suppression techniques, light search and rescue operations and team organization and management. The goal of CERT is to create a well-trained civilian emergency work force as an adjunct to professional forces. CERT trains people to establish neighborhood self-sufficiency during extended emergencies (such as earthquakes) and in situations where the numbers and scope of events overwhelms government emergency forces. The volunteers are trained to perform independently, to train other neighborhood or work area volunteers, to operate teams within their work areas or communities and to work with professional forces in other disaster areas to which they might be assigned. As of 1994 the CERT Program had trained over 12,000 people and its techniques had been adopted by other agencies, including FEMA, to train volunteers throughout the nation.

Following the 8.1 magnitude 1985 Mexico City earthquake, the Department recognized the need for equipment to facilitate rescue of victims trapped in structures and to stabilize hazardous structures. With the support of the City's Emergency Operations Organization, the Department purchased better equipment, including diamond blade power saws and air lifting bags. The equipment proved invaluable in rescuing victims following the 1993 Northridge earthquake.

In 1990, FEMA sponsored a conference in Seattle, Washington for the purpose of developing a national Urban Search and Rescue (US&R) response plan. This led to the formation of 25 Federal Emergency Management Agency (FEMA) US&R Task Forces which are located throughout the nation. Each of the 25 fully equipped, 62-person US&R teams can operate self-sufficiently for 72 hours. They are trained to a high level of expertise in rescue, medical and technical skills and are equipped with specialized equipment capable of dealing with difficult types of building and structural collapses in which people are trapped. The teams rotate the initial on-call responsibility. However, more than one team may be called to assist in a disaster situation. In a major disaster all might be called. The Los Angeles Fire Department is one of the 25 participants in this program. Its FEMA US&R team is maintained in addition to the US&R operations which are part of the Department's on-going US&R program.

Urban development in proximity to brush and hillside terrain makes containment of wild fires difficult. The density and variety of urban development from low rise to high rise structures, traditional commercial and industrial to harbor and airport facilities poses unique fire response and suppression challenges for the City's emergency forces. The broad scope of potential hazards is depicted on Exhibit D, "Selected Wildfire Fire Hazard Areas." The City's fire safety program addresses the broad scope of fire prevention and suppression and emergency response operations.

STORM WATER, INUNDATION AND OTHER WATER ACTION

The water-related hazard programs associated with the Safety Element relate only to those matters which are within the authority and responsibility of the City. However, it is important to understand the context within which the City operates. Water action hazards include major and localized flooding, erosion and landslides as well as potential inundation from water storage facility failure, seiches, mud and debris flows, tsunamis and other ocean wave related hazards. These hazards generally are depicted on Exhibits C (landslide), F (flood plains) and G (inundation and tsunami). Mitigation of water action hazards is a cooperative, multi-jurisdictional effort. It also is related to geologic conditions, seismic, fire and hazardous materials mitigation. To merely set forth the City's specific mitigation responsibilities would leave gaps and raise questions about how related hazards are addressed. Therefore, to provide a comprehensive overview, this section provides a summary of the historic evolution of the roles of various levels of government and how Los Angeles City fits into the overall hazard mitigation efforts.

In general, flood control authority can be summarized as follows: (1) the United States Army Corps of Engineers oversees construction of projects associated with navigable bodies of water, including the Los Angeles River-related flood control systems and ocean harbors; (2) the Los Angeles County Department of Public Works oversees construction of ancillary Los Angeles County Flood Control District facilities and designs and/or maintains the flood control drainage facilities, including the Los Angeles River system (under the guidance of the Army Corps) to mitigate 100- and 500-year storms; and (3) the City Bureau of Engineering oversees construction and maintenance of the City's storm drainage system which is designed to mitigate 50-year magnitude storms. Various City agencies implement development permit, slope stability and watershed protection regulations.

The flood control and storm drainage systems are comprised of the following principal features: (1) debris basins at the mouths of canyons to slow the flow of water and trap boulders, rocks and debris and to prevent clogging of the flow channels; (2) flood control basins (dams) at the upstream portions of the rivers to contain water and regulate downstream flow; (3) containment of over 400 miles of river and tributary systems within mostly open concrete flood control channels; (4) streets, gutters and catch basins to collect and route surface flows to storm drains which carry urban run-off to larger tributary systems and, ultimately, to the flood control channels and ocean; (5) spreading grounds in the San Fernando Valley to impound storm water and allow it to percolate into the ground where it replenishes the underground water system; and (6) associated bridges, reservoirs and water storage facilities. The purpose of the flood control system is to carry storm waters as quickly as possible to the Santa Monica and San Pedro (harbor area) bays to prevent flooding.

Before the flood control system was built, the Los Angeles River and its tributaries flowed freely from the Santa Susana, Santa Monica and San Gabriel Mountains to the sea, flooding large portions of the basins south of the mountains. The Los Angeles basin between the Santa Monica Mountains and Wilmington-San Pedro (future site of the harbor) was dotted with swamp lands and marshes fed by the rivers and streams. Local Spanish names derive from this marshy landscape including "arroyo" (water course), "cienega" (marsh), "zanja" (ditch) and "redondo" (willow). A swamp existed in what is now the Central City. Figueroa Street was called Grasshopper Street and the area became known as "Grasshopper Gulch" due to the insects which lived in the swamp and plagued that part of the community. Today ground water still is very close to the surface in the Wilshire District, feeding the La Brea tar pits, which once entrapped pre-historic animals, and requiring special building design considerations to protect against flooding of subsurface structures. "Brea" is Spanish for "tar."

Capital floods. Major storms which cause a high magnitude of water flow can be devastating to a wide geographic area. They are the most dramatic and potentially the most hazardous water activity confronting the City. The Los Angeles region is a semi-arid region with rainfall which averages 15 inches per year but can vary from 8 to 30 inches per year. Rains tend to occur in heavy, short duration storms between November and April. In a 100-year storm (Exhibit F), 10 to 24 inches of rain may fall within 24-hours or as much as one inch of rain a minute for a brief duration. Severe storms are periodic and may not occur for several years. Paving of the City with structures and impermeable surfaces has eliminated natural ponding areas which allowed water to percolate into the soil. This has facilitated water run-off and velocity of runoff thereby increasing the potential for flooding. Water rushes from streets and other impermeable surfaces along the path of least resistance to the ocean.

Between 1815 and 1938 seventeen major floods were recorded. The 1815 flood cut across what is now the Central City, diverting the Los Angeles River to the Pacific Ocean via Ballona Creek. The flood of 1825 diverted the river from Ballona Creek to its present course. After the 1825 flood, the City was reestablished in the 1815 flood plain without thought of potential future flooding. The floods of 1867-8 destroyed the City's new water system, including a reservoir and a dam intended to divert water for domestic and irrigation needs, changed the course of the San Gabriel River and convinced the City Council to hire the first City Engineer. The 1865-71 droughts devastated farms and the cattle ranches which had characterized the region for a century. To recover losses, ranches, orchards and farms were subdivided and sold. The smaller plots began to be developed with homes, businesses and urban infrastructure. Railroads were extended into the region in 1865, spurring a development boom and accelerating in-migration from the eastern United States. Prior to 1914 there was little interest in providing protection from flooding because the City was rural in character, development was dispersed and major permanent infrastructures had not been constructed. Flooding tended to be localized or occurred in areas not yet inhabited or utilized. As Los Angeles became more urbanized, permanent structures were installed, the population became more concentrated, impermeable surfaces caused more and swifter runoff and flooding increased the threat to life and property.

The first public program in the area to address flooding was the Los Angeles harbor construction project of 1898 which included flood water and silt diversion to protect the harbor. On December 31, 1898 the Army Corps of Engineers, which was charged with the responsibility of improving navigable waterways of the United States, established a 19 man team to plan and build a deep water harbor for the City.

Flood control initially was not within the authority of the Corps, except as it pertained to harbor improvement. The harbor project was completed in 1914. In 1914 over 19 inches of rain fell in four days causing streams and rivers to overflow, turning sections of the Los Angeles basin into islands, severing communications and causing $10 million in property damage, including damage to the harbor. In response, the State, in 1915, created the Los Angeles County Flood Control District to prepare and carry out a flood control plan. Major flooding in 1916 resulted in passage of a County bond issue for the Army Corps to construct the first phase of the flood control system. The project, the Dominguez Narrows by-pass, was completed in 1921. It diverted Los Angeles River flood waters and eliminated harbor silting by emptying flood waters into what is now the Long Beach harbor. Between 1917 and 1939, dams, reservoirs and debris basins were constructed in local mountains, along with some river channel enclosures, but the construction did not keep pace with the explosion in urban growth and was not sufficient to protect the populace. A series of devastating floods between 1921 and 1938 demonstrated the need to establish and carry out a comprehensive flood control plan and resulted in a series of federal acts which gradually expanded the role of the Army Corps and provided funds to construct local drainage systems. The most devastating flood ever experienced by Los Angeles occurred on March 2, 1938. Two days of flooding caused over $40 million in damage and the deaths of 113 people, disrupted the City and again severed communications systems. The disaster resulted in establishment of the first local emergency plan (to aid victims and control looters and sightseers) and adoption of the Drainage Act of 1938 which mandated the Army Corps to prepare a flood control plan for the entire Los Angeles County Drainage Area. The plan was adopted by Congress in 1941 and construction of the system was authorized.

Between 1935 and 1970 the Army Corps oversaw the construction of a system of drainage projects designed to contain the Los Angeles, San Gabriel, Rio Hondo and Santa Ana Rivers as well as Ballona Creek, the Dominguez Channel and other waterways so as to prevent future flooding in the Los Angeles basin from 100-year and 500-year magnitude storms. Two three-day storms in 1943 led to enactment of the National Flood Control Act of 1948 which permitted construction of small flood control projects and performance of emergency work without authorization of Congress. As each phase of the flood control system was completed, except for the dams and dam basins, it was placed under the authority of the Los Angeles County Flood Control District which was charged with maintaining the system (including 58 miles of the Los Angeles River which runs through 13 cities from Calabasas to Long Beach). The principal function of this massive system was to prevent flooding by channeling storm waters so they would be carried as quickly as possible to the sea.

Fire-flood cycles in recent years have increased flood hazards. Rains regenerate growth of vegetation on hillside slopes. The hot summer climate dries out vegetation, creating fuel for fires which destroy the vegetation. Lacking vegetation to slow water flow and enhance water absorption, rain water rushes unimpeded down the fire denuded slopes causing erosion and flooding. Such cycles in 1968-69, 1977-78, 1979-80, 1982-83 and 1994-95 resulted in flooded and washed out streets, destruction of bridges, loss of life, landslides which destroyed hillside and coastal properties, localized but destructive flooding and mud and debris flow inundation of properties below denuded areas.

Since 1940, the City and County have become increasingly urbanized, adding more impermeable surfaces which have increased storm water runoff which in turn has taxed the capacity of the current system during major storms. In 1980 a levee of the Los Angeles River flood control channel near the City of Long Beach was threatened with overtopping by flood waters. This raised concerns about the adequacy of the capacity of the southern sections of the channel to protect adjacent cities. Destructiveness of recent floods and the issue of system capacity have contributed to a re-evaluation of the flood control system by the Army Corps and County Department of Public Works (which in 1985 took over the Flood Control District). They currently are preparing plans to increase the capacity of the Los Angeles River channel in order to meet Federal Emergency Management Agency (FEMA) guidelines for protecting downstream cities from flooding.

Drainage. Within the broad context of regional flood control the City's role is relatively small but critical. It is responsible for construction and maintenance of a storm drainage system within the City's boundaries. The first drainage system was constructed by settlers after the City was established in 1784. Zanjas (ditches) were dug to trap and guide water for drinking, irrigation and drainage. During the 19th Century, wooden (typically redwood) and pottery pipes were added. The first large publicly constructed drainage system may have been the system installed by the Army Corps during the Civil War to drain ponds and wet lands and supply water to the Army's Drum Barracks at Wilmington.

Los Angeles City committed itself to construction of a drainage system after the devastating floods of 1867-68. Contrary to common practice of the time, the storm drainage system was separated from the sewer (i.e., waste water) system and remains separate today, except for treated waste water which is discharged into the flood control system or directly into the ocean. The separation was established following an 1870 report by Frank Lecouvreur, the City's first Engineer, that separation would prevent overwhelming of the sewer system by flood waters associated with periodic major storms. By 1879 a sewer system to take waste water from what is now the civic center to the ocean was under construction. In addition, Lecouvreur designed an east-west street system to assist the flow of rain waters via a street gutter system. The gutters carried storm and daily run off water via the zanjas to ponds and other natural collection areas or to rivers.

The City Bureau of Engineering is charged with overseeing construction of the City's storm drainage system. In addition, the Bureau, under contract to the County, sometimes designs and constructs sections of the County Flood Control system. The City's storm drainage system is integrated with the County Flood Control system and drainage systems of neighboring jurisdictions. The City system consists of streets (including gutters), approximately 1,500 miles of storm drains beneath the streets, approximately 50,000 catch basins which collect runoff from the streets, several large spreading grounds and several pumping facilities. It is designed to accommodate 50-year magnitude storms. During dry weather the combined County and City storm drainage systems carry tens of millions of gallons of runoff (*e.g.*, treated waste water, lawn irrigation, *etc.*) daily. During storms it carries billions of gallons of storm runoff per day. Runoff is carried via open flood control channels directly to the ocean or to collection systems, as envisioned by Lecouvreur in 1870.

Until recent times, the drainage system primarily was financed with public funds or by bond programs. The State Subdivision Map Act of 1907 provided for dedication of land for public purposes. In 1911 the State Improvement Act empowered local governments to use easements, eminent domain, assessment districts and subdivision procedures to secure streets, sewers, drainage and other infrastructure systems. The Subdivision Map Act was amended in 1921 to allow cities to require easements for drainage purposes but legal challenges prevented them from exacting land from property owners. Therefore, dedication of land for public purposes generally continued to be voluntary or was secured through purchase following costly and often lengthy condemnation proceedings. With limited funding available for purchase of easements and construction, development of the system was slow until the Great Depression when federal and state public works programs for the unemployed provided millions of dollars for system construction.

A City's right to withhold building permits for noncompliance with public dedication requirements was upheld by the California Supreme Court in 1966 *(Southern Pacific Railroad versus the City of Los Angeles)*. This decision strengthened the City's ability to secure drainage facilities in conjunction with new development. Local authority was further strengthened by the California Environmental Quality Act of 1971 which required development projects to mitigate potential environmental impacts of proposed projects. Under the State Subdivision Map Act (California Government Code Sections 66410ff), environmental mitigation and City regulations, the City in recent times has required owners of proposed development projects to construct drainage systems to accommodate runoff associated with a project and/or to protect a project and adjacent properties from storm water related hazards associated with the project. This has resulted in a systematic construction of drainage facilities in association with new development projects.

Drainage facilities are built to design specifications determined by the City's Bureau of Engineering. The Bureau in the 1920s established a hydrologic testing laboratory, later called the Hydraulic Research Laboratory. Using mathematical models and dynamic physical models, the lab developed and refined drainage system design and design standards. For specific projects its models were designed to take into account particular site specific factors such as degree of slope, susceptibility to flooding, anticipated velocity of water. The lab also designed associated equipment, including an efficient grate configuration for catch basin grates so grates would not be hazardous to bicyclists, and developed engineering aids such as hydraulic tables, charts and graphs. In the 1980s and 1990s the lab focused on designing wastewater related hydraulic structures. The laboratory incorporated computer technology to assist in hydraulic analysis. However, despite tremendous advances, computer modeling technology is not yet able to achieve the detail and accuracy provided by the lab's physical models. The lab's design innovations and standards have been used not only in development of the Los Angeles storm water and waste water systems and by the City's engineers but have been used by other jurisdictions and private engineers.

Land use planning. Land use planning is important in protecting the public from storm water related hazards. The State Subdivision Map Act allows local jurisdictions to disapprove permits for construction of structures in flood hazard or inundation areas if the hazards cannot be mitigated adequately. The Flood Control Act of 1960 authorized the Army Corps to provide flood maps and information to local jurisdictions to assist them in land use planning. Subsequent federal and state (Cobey-Alquist Flood Plain Management Act, Water Code Section 8401c) legislation encouraged local land use planning, regulations and enforcement in flood prone areas by linking insurance rates and flood management funding to the adequacy of local regulations.

Flood hazard areas, or flood plains which are subject to 100-year floods (Exhibit F), comprise approximately 30 square miles of the City. These areas were mapped by the Federal Emergency Management Agency (FEMA), which deemed that approximately 15 square miles of the hazard areas were buildable. FEMA estimated that over 48,000 structures were located in the hazard areas. To comply with the Flood Disaster Protection Act of 1973, which increased the insurance rates set forth in the National Flood Insurance Act of 1968 and required local floodplain regulations to have enforcement provisions, the City of Los Angeles adopted the 1980 Flood Hazard Management Specific Plan (amended in 1988 by Ordinance 163,913). The ordinance establishes annexation procedures and permit review and mitigation procedures for issuance of development permits in areas prone to flooding, mud flow or coastal inundation. It also specifies the responsibilities of City agencies which process the permits. Mitigation measures include relocation of structures within a property, increased base elevation, additional structural reinforcement, anchoring, and installation of protective barriers. A permit can be denied if mitigation is deemed insufficient to protect human life. Compliance with the National Flood Insurance Act makes the City eligible for FEMA funds and reduced federal flood insurance rates. In addition, the General Plan community plan elements establish land use designations (zoning categories) for all properties within the City, in compliance with State land use requirements. Flood inundation areas generally are classified in the lowest density zoning categories.

Mud and debris slides and localized flooding. Watershed protection is a primary concern of the City, especially in hillside areas (Exhibit C). Permeable soil soaks up rain and irrigation water, proper grading and drainage systems channel and collect water to protect slopes from saturation and slippage, catch basins divert surface water to street gutters which divert the water to storm drains and flood control channels so as to reduce erosion and flooding. The Bureau of Engineering, Building and Safety Department, Planning Department and Fire Department coordinate development permit review and issuance to assure proper grading, drainage, irrigation and landscaping so as to preserve slope stability, provide erosion control and reduce potential for flooding and fire hazard.

Following major brush fires, federal or state agencies typically seed denuded areas with wild plant seeds which rapidly germinate thereby encouraging regeneration of vegetation which will hold the soil and protect the watershed from erosion. Remedial measures, such as sandbagging and erection of temporary erosion control measures, are instituted in anticipation of storms so as to protect road systems and property from potential landslides, flooding and mud and debris flows. To reduce fire hazards and protect slopes, the City requires vegetation clearance and encourages hillside property owners to plant appropriate vegetation and to implement proper irrigation and slope maintenance measures.

Beach erosion. Beach erosion mitigation is under the auspices of the Army Corps. Taming of flood waters of the Los Angeles River and draining of marshes, dredging, construction of breakwaters and creation of new land masses for development of the harbors changed ocean wave action and reduced the flow of natural sediments (sand) to the sea. Change in wave action and lack of sand to replenish beaches resulted in erosion of the coastline, undermining of cliffs and reducing or eliminating beaches. Undermining of cliffs sometimes resulted in landslides and loss of homes and property. Initially local jurisdictions were responsible for beach protection. In the 1930s the Bureau of Engineering Hydraulic Research Laboratory evaluated sand migration to identify causes of erosion and means of mitigating erosion and protecting roadways and properties. It became clear the that primary cause of beach erosion was due to the breakwaters and other Army Corps constructed modifications of wave action along the coast. Mitigation generally was beyond the expertise and resources of local jurisdictions. In 1956 damage had become so serious that Congress expanded the role of the Corps to include responsibility for beach erosion management, *e.g.*, beach protection and replenishment.

Tsunamis and large ocean waves. Tsunamis are large ocean waves which are generated by major seismic events. Storms at sea also can generate heavy waves. Both have the potential of causing flooding of low lying coastal areas. Exhibit G depicts potential tsunami hazard areas. Hazardous tsunamis are rare along the Los Angeles coast. However, storm generated waves have caused considerable damage to property and beaches along the ocean perimeter. The City Flood Hazard Specific Plan sets forth design criteria for development in coastal zones, including increased base building elevations. The Army Corps is responsible for constructing and maintaining the breakwaters which are designed to mitigate damaging wave action, particularly in the harbor area. The Harbor Department works cooperatively with the Army Corps relative to maintenance and protection of the breakwater facilities. Along with the fire and police departments, it participates in the federal tsunami alert program to warn potentially affected properties and harbor tenants of tsunami threats and to advise them concerning protective response actions.

Seiches and inundation (water storage facilities). A seiche is a surface wave created when a body of water is shaken. Seiches are of concern relative to water storage facilities because inundation from a seiche can occur if the wave overflows a containment wall, such as the wall of a reservoir, water storage tank, dam or other artificial body of water. Mitigation of potential seiche action has been implemented by the Department of Water and Power through regulation of the level of water in its storage facilities and providing walls of extra height to contain seiches and prevent overflow. Dams and reservoirs are monitored during storms and measures are instituted in the event of potential overflow. These measures apply to facilities within the City's borders and facilities owned and operated by the City within other jurisdictions.

Inundation due to water storage facility failure also is a potential hazard. The Baldwin Hills dam failure of December 14, 1963 and near collapse of the Van Norman Dam during the 1971 San Fernando earthquake resulted in strengthening of the federal, state and local design standards and retrofitting of existing facilities. Thirteen dams in the greater Los Angeles area moved or cracked during the 1994 Northridge earthquake. The most seriously damaged was the Pacoima Dam which was located approximately eight miles from the epicenter. However, none were severely damaged. This low damage level was due in part to completion of the retrofitting of dams and reservoirs pursuant to the 1972 State Dam Safety Act following the San Fernando quake. The Act also required the preparation of inundation maps. Significant potential inundation hazard areas are depicted on Exhibit G.

Ecological systems. Environmental considerations are an important part of flood control systems. As the Los Angeles flood control system neared completion and public demand for water supplies, recreation and beautification increased, Congress provided for multiple use of facilities. By the 1960s watershed protection, electrical power, recreation, agriculture and water storage were integral secondary uses of flood control systems and considerations in flood control systems planning. Paving of the Los Angeles River bottom, and City in general, reduced ground water recharge. To compensate for the loss, water spreading grounds were established to replenish underground aquifers. Three sections of the Los Angeles River have unpaved bottoms partially due to the existence of natural springs. These sections and dam basins provide natural habitats for wild animals and birds. The dam basins also provide land for recreation and agricultural uses. Sand bars, trees and heavy marsh growth provide protected habitats for water birds. Fish live in the river channel. Until 1984, the Los Angeles River channel, except for the unpaved sections, virtually was dry except during the rainy season. Upon completion of the San Fernando Valley Donald C. Tillman Wastewater Reclamation Plant (1984) a continuous flow of reclaimed water was sent down the channel creating a year round stream which has regenerated plant and animal life along the entire channel. Some hiking, equine and bicycle trails exist and are planned for expansion along the edges of some flood control channels.

Water quality. Water quality relative to drainage was an early consideration of the City. Public funds began to be expended in the late 1880s for construction of public works, including streets with gutters and associated drains. The sewage and water drainage systems were separated so as to keep storm and drainage water from entering the sewage system and to enable large quantities of rain water to be carried rapidly to the ocean without necessity of treatment. In the 1920s sewer maintenance hole covers near gutters were sealed to keep out storm water and an inspection unit was established to identify and cite property owners for illegal connections from roofs, yards, wash racks and the like into the sewer system. In recent years pollution of drainage water has become an increasing concern.

Prior to 1958 the primary concern relative to water pollution related to pollution of ocean and beaches due to oil tanker spills. Such spills were regulated by federal agencies. Beginning with the Water Pollution Control Act of 1956, the federal government began to address the problem of pollution discharge into navigable waters, such as the Pacific Ocean. Initially, this resulted in regulations of discharge of waste water (sewage). More recently, federal regulations have focused on storm water, urban runoff and dumping of pollutants into storm drainage systems. Daily runoff in dry or wet periods washes residues from the land, including deposits from vehicles, pet waste, pesticides and street litter. Illegal dumping of waste into the storm drainage system adds to the run-off stream. The first rains of the season wash accumulated pollutants from streets, vegetation and roof tops into the drainage system. Even natural seepage, such as from the La Brea tar pit area or other oil and gas deposits which underlay large sections of the City, or from microorganisms in the soil, contribute pollutants. Pollutants also are washed from the air onto the land and into the run-off stream. Air quality aspects of pollution are addressed in the General Plan Air Quality Element.

Storms result in inflow and infiltration into sewage systems and have caused release into the ocean of partially treated sewage. Sometimes discharge washed into the ocean during storms has resulted in temporary beach closure due to potential health hazards associated with harmful bacteria from human and animal waste and decomposed plant material which is washed from land surfaces into the ocean by storms or which results from leak incidents. There also is concern that storm related residues may contribute damage to the ecology of the local bays, estuaries and natural water supported habitats.

To address potential hazards of discharge and run-off, the Federal Clean Water Act (*i.e.*, Water Pollution Control Act) was amended in 1972 making it unlawful to discharge water borne pollutants into navigable waters of the United States from any point source, except as allowed by a National Pollutant Discharge Elimination System (NPDES) permit. A "point source" being an identifiable source of discharge such as from a ship, pipe, fissure, or container, as opposed to non-point sources, such as water borne run-off containing pollutants from sources which are not readily identifiable. In 1973 the Federal Environmental Protection Agency (EPA) issued regulations to implement the Act and specifically exempted urban runoff that was not contaminated by industrial or commercial sources. The State Water Resources Control Board and its regional boards were charged with enforcing the regulations and issuing the permits. In Los Angeles, the regulations were interpreted to apply to City sewage and industrial waste water discharges into the Pacific Ocean and not to storm water or urban runoff.

To more clearly address the issue of storm water and urban runoff, the Clean Water Act was amended in 1987 to require NPDES permits for any discharge into navigable waters of the United States. The intent of the amendment was to address non-point sources and general urban and storm water runoff, especially residues from routine industrial and commercial activity. Such residues are washed by storm water from surfaces and the land and are carried via the drainage systems to the ocean. There was recognition in broadening the regulations that it was difficult to assess non-point source pollution and that further data and evaluation of run-off was needed.

In 1988-90 the EPA issued storm water discharge regulations to implement the 1987 amendments. The City joined with Los Angeles County and other municipalities within the County in ubmitting a joint NPDES permit which was approved by the Los Angeles Regional Water Quality Control Board in June 1990. The permit was applicable for five years. The involved jurisdictions were in the process of renewing the permit at the time this Safety Element was being prepared. Water pollution issues and programs are addressed more comprehensively by other elements of the General Plan.

SLOPE FAILURE AND SUBSIDENCE

Los Angeles is a part of the Pacific Coastal Region, a huge geologic region which stretches from Alaska to the tip of South America. The region consists of young geologic areas in which the mountains still are in the process of growing and shaping the California land form. Los Angeles is one of the few major cities in the world with a mountain range (the Santa Monica Mountains) bisecting its land area. In addition, it is bounded by the Santa Susana and Verdugo Mountains and the Palos Verdes Hills. The Beverly Hills and Baldwin Hills bound or cross other sections of the City. The Pacific Ocean interacts with the coastal boundaries of these ranges to create seaside cliffs and beaches. Under natural conditions, slopes often give way, resulting in landslides. Exhibit C generally depicts some of the significant potential landslide hazard areas. As City development spread from the flat lands of what is now the Central City and the San Fernando Valley into the hillsides and along the bases of slopes, unstable soil and erosion sometimes contributed to landslides and mud and debris flows which impacted development, especially following rain storms. Landslides can be triggered by natural causes such as earthquakes, ocean wave action or saturation by storm, or can be induced by the undercutting of slopes during construction, improper artificial compaction or saturation from sprinkler systems or broken pipes.

The principal tool for mitigation of geologic hazards is the City Grading Code. In 1929 the Building and Safety Department began to compile and correlate data on soil conditions for distribution to realtors, builders and prospective property buyers. In 1952 hillside grading provisions were added to the Building Code. Los Angeles was the first city in the nation to have such provisions. Storms of 1957-58 caused extensive damage in hillside areas and led to adoption of the 1963 Grading Code. It was the first such legislation in the nation and served as a model for other jurisdictions. A unique feature of the Code was a requirement that professional geologists supervise hillside grading. Under the Code the Department of Building and Safety has the authority to withhold building permit issuance if a project cannot mitigate potential hazards to the project or which are associated with the project. A property owner may be required to install pilings to anchor a structure to bedrock, to construct retaining walls, build drainage systems or implement other mitigation measures. If, after a project is constructed, potential slope stability hazards are identified, the City can require implementation of stabilization measures. The Grading Code periodically is revised to reflect new technology and improve standards and requirements. Pursuant to the State Hazard Mapping Act, the State Geologist is preparing maps which identify potential landslide hazard areas. A description of this program is contained in the "Seismic Events" section of this Element.

To regulate subsurface extraction activities, the City established Oil Drilling District procedures in 1948 and Rock and Gravel District procedures in 1951. The latter was superseded in 1976 by the Surface Mining District ordinance which brought the City into compliance with the California Surface Mining and Reclamation Act of 1975. The former has been amended several times to improve protective and procedural measures and, in 1971, to include offshore oil drilling. Both contain provisions for monitoring and imposing mitigation measures to prevent significant subsidence relative to oil and gas extraction and mining activities. The districts (Exhibit E) are established as overlay zones and are administered by the City Planning Department with the assistance of other City agencies. The City Oil Administrator of the Office of the City Administrative Officer is responsible for monitoring oil extraction activities and has the authority to recommend additional mitigation measures to the Planning Commission after an Oil Drilling District is established. The Planning Department Office of Zoning Administration issues and administers oil drilling permits and may impose additional mitigation measures, as deemed necessary, after a permit has been granted, such as measures to address subsidence.

SEISMIC EVENTS

The programs associated with this Safety Element emphasize seismic safety issues because seismic events present the most widespread threat of devastation to life and property. With an earthquake, there is no containment of potential damage, as is possible with a fire or flood. Unlike a fire or flood whose path often can be generally measured and predicted, quake damage and related hazard events may be widespread and, at present, are unpredictable. Related hazard events could occur anywhere in the quake area including inundations from damaged reservoirs or release of hazardous materials, such as gas, which in turn could lead to fires or form toxic clouds.

Since 1800 there have been approximately 60 damaging seismic events, or "earthquakes," in the Los Angeles region. After a brief hiatus between major events (circa 1940-1972), the greater Los Angeles area has experienced a number of moderate events which have resulted in considerable disruption of the infrastructure, impact on social and economic life, loss of lives and extensive property damage within the City, the greater metropolitan area and the adjacent region. The most recent of these was the 6.7 magnitude 1994 Northridge earthquake which was centered in the northwest part of the City, in the general vicinity of the 1971 San Fernando (aka Sylmar) quake.

The U.S. Geological Survey has estimated the probability of a ten to thirty percent potential for a 7.5 or more magnitude quake along the southern portion of the San Andreas fault within the next five to thirty years. The Alquist-Priolo Act requires the State Geologist to map active earthquake fault zones. Those faults in the Los Angeles area typically are visible, above ground faults, *e.g.*, the San Andreas fault. The fault zones located within the City are depicted on Exhibit A. However, it is the quakes along the unmapped faults, such as the blind thrust fault associated with the Northridge earthquake, that increasingly are becoming the focus of study and concern. The concept of blind thrust faults has been recognized only recently by seismologists. The effect of such faults may dominate the geology of the Los Angeles basin in a way not previously known.

Seismic mitigation is relatively new, compared to flood and fire mitigation. Every major seismic event in the United States and abroad has provided valuable data for evaluating existing standards and techniques and improving hazard mitigation. The 6.3 magnitude Long Beach earthquake of 1933 killed 115 people and caused approximately $48 million in property damage. It demonstrated the vulnerability of unreinforced masonry structures and the hazards of parapets and unanchored facade decorations. In response, the State legislature adopted the Field Act of 1934 which set seismic building standards. Locally the reinforcement and parapet standards were adopted for new construction. The nature of damage to Seattle, Washington, due to the 1949 earthquake, persuaded Los Angeles to require removal of parapets and decorative appendages so as to prevent unreinforced masonry and concrete from falling onto streets and sidewalks during a quake. The ordinance was applicable to some 30,000 pre-1933 buildings which were located predominantly in the Central City area. The 1985 Mexico City earthquake prompted the City to upgrade and expand its urban search and rescue program (see Fire Section).Following the 1971 San Fernando quake, the City required improved anchoring of new tilt-up (concrete walls poured and tilted-up on the site) structures and retroactive reinforcement of unreinforced masonry structures. A seismic retrofit tilt-up ordinance was developed and made retroactive two weeks after the 1994 Northridge earthquake. Subsequently, the City adopted a series of ordinances which required retrofitting of certain existing structures (*e.g.*, foundation anchoring of hillside dwellings) and for new construction, as well as an ordinance which required evaluation of structures by a structural engineer during the construction process. The Northridge quake underscored the need for thorough, on-going building inspections to assure construction of buildings according to Code.

Although the Northridge earthquake was listed by seismologists as a moderate quake, it was the most costly seismic event in the United States since the 1906 San Francisco earthquake. Within the City and surrounding region, approximately 72 people died as a result of the quake (including by heart attack associated with the quake experience), thousands were physically injured, and the direct and indirect psychological toll was incalculable. Property damage was in the billions of dollars. An estimated

93,000 (as of June 1996) buildings were damaged in the City, some requiring demolition. Approximately 5,800 buildings had to be partially or totally vacated, including approximately 25,640 mostly multiple-residential dwelling units. By the autumn following the quake, some 27,000 units were deemed in danger of being lost because owners had difficulty financing repair costs.

In addition, the infrastructure (Exhibit H) of the metropolitan area was severely disrupted. Freeways collapsed, the power systems for the City and linked communities as far away as Oregon were temporarily "blacked out" and communications were disrupted. Due to abatement measures, planning, training and inter-agency and inter-jurisdictional coordination, response was much more efficient than in 1971 following the San Fernando quake. Stronger building codes and required retrofitting following the San Fernando quake contributed to a reduction in damage to structures and buildings and resulted in better containment of hazardous materials. Coordinated response resulted in more rapid identification of damage sites, extinguishing of fires, addressing of fire hazards, administering, often from battle-field like temporary facilities, to the injured and displaced and initiation of work to restore the disrupted cities and region. Closure of businesses, disruption of services and dislocation of people had a significant domino effect on the economy of the region, state and nation. The economic impact would have been greater had the quake been more severe or had disruption of the infrastructure continued for a longer period of time.

The fact that the Northridge event occurred at 4:31 a.m. January 17, 1994 on the Martin Luther King Jr. national holiday may have been the primary reason for so little loss of life and human injury. A low number of commuters were traveling on the freeways and streets and few people were in offices, industrial, commercial buildings, public garages and shopping centers, many of which suffered severe structural and non-structural damage. Many emergency and seismic experts believe that had the quake occurred at midday, instead of during the predawn, the loss of life and injury figures would have been substantially higher. Nevertheless, emergency forces were severely challenged by the event.

The Northridge quake was one of the most measured earthquakes in history due to extensive seismic instrumentation in buildings and on the ground throughout the region. Information from seismological instruments, damage reports and other data provided a wealth of information for experts to analyze. Traditional theories about land use siting and existing building code provisions were called into question. It is known that the complex Los Angeles fault system interacts with the alluvial soils and other geologic conditions in the hills and basins. This interaction appears to pose a potential seismic threat for every part of the City, regardless of the underlying geologic and soils conditions. Structural damage does not occur due to any one factor. The duration and intensity of the shaking, distance from the epicenter, composition of the soil and type of construction, all are factors in determining the extent of damage which may occur. Alluvial and artificially uncompacted soils tend to amplify the shaking. Shallow ground water, combined with uncompacted soils can result in liquefaction (quicksand effect) during a strong quake. Therefore, it is difficult to escape the impacts of a quake. During the Northridge quake, damage appeared to have a more direct relationship to building construction than did proximity to the epicenter. Largely as a result of the Northridge earthquake, the national Uniform Building Code was amended in 1994 to require that new development projects provide geotechnical reports which assess potential consequences of liquefaction and soil strength loss and propose appropriate mitigation measures, *e.g.*, walls supported by continuous footings, steel reinforcement of floor slabs, *etc.* These provisions were incorporated into the Los Angeles City Building Code, effective January 1996. Exhibit B identifies, in a general manner, areas susceptible to liquefaction. It was prepared for the General Plan Framework Element environmental impact report and is based on the County of Los Angeles 1990 Safety Element liquefaction exhibit. It identifies areas deemed to be liquefaction or potential liquefaction areas, based on occurrences of shallow ground water together with recent alluvial deposits.

One of the surprising findings following the Northridge quake was that many steel frame buildings, believed before the quake to be the safest structures, suffered unexpected welding joint damage. Such damage resulted in the evacuation of an 11-story building in West Los Angeles several months after the quake when it was determined that the damage to building joints had dangerously weakened the building structure. The building was located miles from Northridge, in the basin on the other side (south) of the Santa Monica Mountains. At the time this Safety Element was under preparation experts had not determined an acceptable method for retrofitting such buildings.

These are important findings for Los Angeles because Los Angeles is a built city. Few large tracts of land remain which have not already been developed with some use. Many key facilities, such as freeways, already follow fault lines through mountain passes. Buildings already are built on uncompacted and alluvial soils. Part of the downtown center, including its many high rise buildings, is built near the Elysian Park blind thrust fault which many seismologists believe could be the source of a major seismic event in the not so distant future. Physical expansion and change in the City will occur primarily through rehabilitation of existing structures and redevelopment of existing neighborhoods. The City's biggest challenge is how to protect an existing city and its inhabitants from future damage. Many believe this should be accomplished through improved building design instead of prohibition of construction. At the time this Element was under preparation, the City was retrofitting City Hall and some Port of Los Angeles facilities with base isolators to make the structures less prone to failure during strong ground shaking. This type of retrofitting is a step in addressing the strengthening of built structures.

Pre-seismic event land use planning with a view to reconfiguring the devastated areas though post-event changes in land use, intensity of development, *etc.* generally are not included as programs of this Safety Element. It has been the City's experience that the unpredictability of seismic events, both as to location and damage, renders such planning impractical. Devastation, while widespread, generally does not completely destroy entire blocks, neighborhoods or large geographic areas. Therefore, rebuilding tends to be more of an infill activity than an urban clearance and reconstruction enterprise. However, traditional redevelopment programs are included in the optional tools available for reconstruction of severely damaged areas and are being used to rebuild neighborhoods devastated by the Northridge quake.

Hazard assessment. The State Public Resources Code Section 2699 requires that a safety element "take into account" available seismic hazard maps prepared by the State Geologist pursuant to the Alquist-Priolo Earthquake Fault Zoning Act of 1972, subsequently amended (Public Resources Code Sections 2621-2630, originally known as the Alquist-Priolo Special Studies Zones Act) and the Seismic Hazard Mapping Act of 1990, subsequently amended (Public Resources Code Sections 2690-2699.6 and 3720-3725). The Alquist-Priolo Act was established as a direct result of the 1971 San Fernando earthquake. It requires that the State Geologist map active faults throughout the State. Those maps which are applicable to the City of Los Angeles are incorporated into Exhibit A of this Safety Element.

The Hazard Mapping Act requires the State Geologist to map areas subject to amplified ground shaking (or conditions which have potential for amplified ground shaking), liquefaction and landslide hazard areas. Following the 1994 Northridge earthquake, the hazard mapping program was revised and accelerated. The maps were under preparation concurrently with the preparation of this Safety Element. The first liquefaction and landslide hazard maps are scheduled to be released in 1996. Ground shaking maps are scheduled for release beginning in 1997. The entire mapping program is expected to be completed around 1999. Local jurisdictions are required by the Mapping Act to require additional studies and appropriate mitigation measures for development projects in areas identified as potential hazard areas by the maps. As maps are released for Los Angeles they will be utilized by the Building and Safety Department in helping to identify areas where additional soils and geology studies are needed for evaluation of hazards and imposition of appropriate mitigation measures prior to issuance of building permits. Once the entire set of maps for Los Angeles is complete it will be used to revise the soils and geology exhibits of this Safety Element. The maps, along with information being developed by private technical organizations, such as the Southern California Earthquake Center and California Institute of Technology, will assist the City in evaluating how to strengthen its land use and development codes and development permit procedures so as to better protect life and property from seismic hazards. The Building Code already has been revised utilizing data secured relative to the Northridge and other recent significant seismic events. The subject Safety Element fulfills current requirements, based upon available official maps and reliable data, relative to fault zones (Exhibit A), liquefaction areas (Exhibit B) and slope failure (Exhibit C). These exhibits will be revised following receipt of the reliable new information. In addition to the hazard mapping provisions, the State requires that property sellers or agents disclose to potential property buyers geotechnical reports and their contents.

HAZARDOUS MATERIALS

Hazardous materials have been a concern since 1900 when the City experienced its first major oil industry fire. Extraction of oil and gas deposits began in 1896 when Edward Doheny discovered oil at Second Street and Glendale Boulevard (Westlake community). By 1900 he had erected over 600 wooden oil rigs and installed hundreds of storage tanks and related facilities. In that year a family bonfire ignited the oil field at Bixel Street. An estimated 10,000 gallons of blazing oil spilled down the hills but was diverted and suppressed before it reached the densely built Central City. The saving of the downtown from a potential disaster prompted the City to purchase more fire suppression equipment and to expand the number of fire stations and personnel. Subsequent oil field fires in the Doheny and other fields throughout the City resulted in regulations to assure containment of oil fires in oil fields, refineries and oil and gas storage facilities.

Much of the area south of the Santa Monica Mountains is underlain by gas and oil deposits. Such deposits exist under other areas of the City as well (Exhibit E). Natural gas, crude oil and hydrogen sulfide can work their way to the surface or infiltrate structures, causing potential fire and health hazards. In addition, landfills are sources of methane gas. The existence of underground gas and hazardous materials deposits requires monitoring of excavations and known seepage areas. A major incident occurred in 1971 during the tunneling for the Feather River Project when a methane explosion killed 18 workers. Incidents relating to the gas seepage caused temporary safety shutdowns of the Metro Rail subway tunneling in 1993-95.

In the 1920s the use of chemicals and hazardous materials in the City's expanding manufacturing and commercial sectors increased the hazards for both workers and the general populace. A series of movie studio back lot fires and film processing laboratory fires occurred in the late 1920s. These incidents led to the enactment of City regulations to protect workers and the public from fires and fumes associated with highly flammable film and chemicals used in film processing as well as from hazards associated with flammable movie sets.

Today hazardous materials are used in commercial, industrial, institutional and agricultural enterprises as well as households throughout the City. Los Angeles operates both a major international airport and a major harbor within its boundaries and operates other airport facilities within and outside its boundaries. Hazardous and highly flammable materials are shipped through, stored and used (especially fuels) at these facilities. They also are transported along freeways and highways and are stored in facilities throughout the City. Many hazardous materials, if released by accident or catastrophic event, could cause severe damage to human life and health and to the facilities and could disrupt activities within a radius of several miles around the release site.

During the 1994 Northridge earthquake, over 100 incidents of quake related release of hazardous materials were reported. Of these, 23 involved release of natural gas, 10 involved release of gases and liquid chemicals at educational institutions and 8 involved release of hazardous materials at medical facilities. Gas leaks or chemical reactions triggered fires which destroyed or damaged nine university science laboratories. Rupture of a high pressure natural gas line under Balboa Boulevard in Granada Hills resulted in a fire which damaged utility lines and adjacent homes. Petroleum pipeline leaks released 4,000 barrels of crude oil into the Santa Clara River north of Los Angeles and caused fires in the Mission Hills section of the City.

Fires can damage labeling and warning signs which are posted on chemical and fuel containers and on structures to identify presence of hazardous materials. Identification of hazardous materials, storage and handling sites and information about containment facilities and/or procedures are important to protect emergency personnel as well as employees and the adjacent community during a spill incident and incident clean-up.

Hazardous materials management is regulated by federal and state codes. Within the City, the Fire Department is designated as the enforcement agency for the City, state and federal hazardous materials regulations. City regulations include spill mitigation and containment and securing of hazardous materials containers to prevent spills. In addition, the State Fire Marshall enforces oil and gas pipeline safety regulations and the federal government enforces hazardous materials transport pursuant to its interstate commerce regulation authority. At the time this Safety Element was under preparation cooperative interjurisdictional efforts were underway to evaluate the Northridge, Kobe and other seismic experiences and to develop methods for reducing potential hazardous materials spills and related damage associated with seismic events.

In 1976 the bulk oil tanker S.S. Sansinena exploded in the Port of Los Angeles killing nine people, injuring 46 and causing an estimated $21.6 million in damage. The tanker was empty. Poor maintenance and operating procedures on board the ship were identified as the cause of the explosion. In response to this incident, the City Council adopted a unique ordinance which required the Fire Department to inspect all tanker ships in the Port prior to loading and unloading so as to assure compliance with City fire prevention and safety measures and regulations. Los Angeles is the only City in the nation which has established such a program.

The Fire Department works cooperatively with the United States Coast Guard, the State and Los Angeles County in responding to off-shore emergency incidents including responding to, containing and cleaning-up off-shore oil spills. The City's authority is to protect the shoreline (on-shore). In accordance with a mutual aid agreement with the U.S. Coast Guard, the Fire Department provides the initial response to any spill in the harbor or off-shore. Its responsibility is to contain the initial spill and keep the situation from getting worse. The County is responsible for coordinating clean-up efforts. At the time this Safety Element was being prepared, the State was preparing a statewide Coastal Oil Spill Contingency Plan to establish administrative procedures (*e.g.*,chain of command) for responding to spills and providing clean-up, including training and utilization of volunteers in clean-up operations. The Fire Department's spill contingency plan will be incorporated into the State plan.

As noted above, this Safety Element primarily addresses hazardous materials relative to other potential natural hazards. Landfill monitoring is addressed by another element of the General Plan and by the City's Integrated Solid Waste Management Plan.

CHAPTER III - GOALS, OBJECTIVES AND POLICIES

The Safety Element goals, objectives, policies and programs are broadly stated to reflect the comprehensive scope of the Emergency Operations Organization (EOO). The EOO is the only program that implements the Element. The Element's policies outline administrative considerations which are addressed by EOO procedures, including its Master Plan, or which are observed in the carrying out of the Plan. All City agencies are part of the EOO. All City emergency preparedness, response and recovery programs are integrated into EOO operations and are reviewed and revised continuously.

Because City codes and regulations contain standards for water, streets, *etc.*, the Safety Element programs generally do not contain specific standards. An exception is the Fire Code policy which contains standards which, at the time this Element was under preparation, were contained only in the 1979 Fire Protection and Prevention Element of the General Plan. Until the standards are incorporated into the Fire Code or other regulations or plans, this is the only place where they are located. They are needed to guide City development actions. Other standards which were listed in the 1979 Fire Protection and Prevention Element have been incorporated into City Codes or superseded by other regulations or procedures.

HAZARD MITIGATION

GOAL 1

A city where potential injury, loss of life, property damage and disruption of the social and economic life of the City due to fire, water related hazard, seismic event, geologic conditions or release of hazardous materials disasters is minimized.

Objective 1.1

Implement comprehensive hazard mitigation plans and programs that are integrated with each other and with the City's comprehensive emergency response and recovery plans and programs.

Policies

1.1.1 Coordination. Coordinate information gathering, program formulation and program implemen tation between City agencies, other jurisdictions and appropriate public and private entities to achieve the maximum mutual benefit with the greatest efficiency of funds and staff. [All EOO hazard mitigation programs involving cooperative efforts between entities implement this policy.]

1.1.2 Disruption reduction. Reduce, to the greatest extent feasible and within the resources available, potential critical facility, governmental functions, infrastructure and information resource disruption due to natural disaster. [All EOO programs involving mitigation of disruption of essential infrastructure, services and governmental operations systems and prepare personnel for quickly reestablishing damaged systems implement this policy.]

1.1.3 Facility/systems maintenance. Provide redundancy (back-up) systems and strategies for continuation of adequate critical infrastructure systems and services so as to assure adequate circulation, communications, power, transportation, water and other services for emergency response in the event of disaster related systems disruptions. [All EOO programs that involve provision of back up systems and procedures for reestablishment of essential infrastructure, services and governmental operations which are disrupted implement this policy.]

1.1.4 Health/environmental protection. Protect the public and workers from the release of hazardous materials and protect City water supplies and resources from contamination resulting from accidental release or intrusion resulting from a disaster event, including protection of the environment and public from potential health and safety hazards associated with program implementation. [All EOO hazardous materials hazard and water pollution mitigation programs implement this policy.]

1.1.5 Risk reduction. Reduce potential risk hazards due to natural disaster to the greatest extent feasible within the resources available, including provision of information and training. [All programs that incorporate current data, knowledge and technology in revising and implementing plans (including this Safety Element), codes, standards and procedures that are designed to reduce potential hazards and risk from hazards potentially associated with natural disasters implement this policy.]

1.1.6 State and federal regulations. Assure compliance with applicable state and federal planning and development regulations, *e.g.*, Alquist-Priolo Earthquake Fault Zoning Act, State Mapping Act and Cobey-Alquist Flood Plain Management Act. [All EOO natural hazard enforcement and implementation programs relative to non-City regulations implement this policy.]

EMERGENCY RESPONSE (Multi-Hazard)

GOAL 2

A city that responds with the maximum feasible speed and efficiency to disaster events so as to minimize injury, loss of life, property damage and disruption of the social and economic life of the City and its immediate environs.

Objective 2.1

Develop and implement comprehensive emergency response plans and programs that are integrated with each other and with the City's comprehensive hazard mitigation and recovery plans and programs.

Policies

2.1.1 Coordination. Coordinate program formulation and implementation between City agencies, adjacent jurisdictions and appropriate private and public entities so as to achieve, to the greatest extent feasible and within the resources available, the maximum mutual benefit with the greatest efficiency of funds and staff. [All EOO response programs involving cooperative efforts between entities implement this policy.]

2.1.2 Health and environmental protection. Develop and implement procedures to protect the environment and public, including animal control and care, to the greatest extent feasible within the resources available, from potential health and safety hazards associated with hazard mitigation and disaster recovery efforts. [All EOO emergency response and recovery programs that mitigate environmental impacts or provide care and control of animals injured or released by an emergency situation implement this policy.]

2.1.3 Information. develop and implement, within the resources available, training programs and informational materials designed to assist the general public in handling disaster situations in lieu of or until emergency personnel can provide assistance. [All EOO response programs involving training, collection and dissemination of warning, guidance and assistance information to the public implement this policy.]

2.1.4 Interim procedures. Develop and implement pre-disaster plans for interim evacuation, sheltering and public aid for disaster victims displaced from homes and for disrupted businesses, within the resources available. Plans should include provisions to assist businesses which provide significant services to the public and plans for reestablishment of the financial viability of the City. [All EOO response and recovery programs involving evacuation and provision of temporary services to victims of an emergency event and any planning and training related thereto implement this policy.]

2.1.5 Response. Develop, implement and continue to improve the City's ability to respond to emergency events. [All EOO emergency response programs and all hazard mitigation and disaster recovery programs related to protecting and reestablishing communications and other infrastructure, service and governmental operations systems implement this policy.]

2.1.6 Standards/fire. Continue to maintain, enforce and upgrade requirements, procedures and standards to facilitate more effective fire suppression. [All peak load water and other standards, code requirements (including minimum road widths, access, clearances around structures) and other requirements or procedures related to fire suppression implement this policy.]

The Fire Department and/or appropriate City agencies shall revise regulations or procedures to include the establishment of minimum standards for location and expansion of fire facilities, based upon fire flow requirements, intensity and type of land use, life hazard, occupancy and degree of hazard so as to provide adequate fire and emergency medical event response. At a minimum, site selection criteria should include the following standards which were contained in the 1979 General Plan Fire Protection and Prevention Plan:[6]

• Fire stations should be located along improved major or secondary highways. If, in a given service areas, the only available site is on a local street, the site must be on a street which leads directly to an improved major or secondary highway.

• Fire station properties should be situated so as to provide drive-thru capability for heavy fire apparatus.

• If a fire station site is on the side of a street or highway where the flow of traffic is toward a signalized intersection, the site should be at least 200 feet from that intersection in order to avoid blockage during ingress and egress.

• The total number of companies which would be available for dispatch to first alarms would vary with the required fire flow and distance as follows: (a) less than 2,000 g.p.m. would require not less than 2 engine companies and 1 truck company; (b) 2,000 but less than 4,500 g.p.m., not less than 2 or 3 engine companies and 1 or 2 truck companies; and (c) 4,500 or more g.p.m., not less than 3 engine companies and 2 truck companies.

[These provisions, in full or in part, shall be deemed deleted from the Safety Element upon incorporation of these or substitute provisions into the Fire Code, Fire Chief Regulations, other appropriate regulations or procedures or another General Plan element.]

2.1.7 Volunteers. Develop and implement, within the resources available, strategies for involving volunteers and civic organizations in emergency response activities. [All EOO response programs involving volunteers implement this policy.]

[6] *These provisions of the 1979 Plan were modified by the Fire Department for purposes of clarification .*

DISASTER RECOVERY (Multi-Hazard)

GOAL 3

A city where private and public systems, services, activities, physical condition and environment are reestablished as quickly as feasible to a level equal to or better than that which existed prior to the disaster.

Objective 3.1

Develop and implement comprehensive disaster recovery plans which are integrated with each other and with the City's comprehensive hazard mitigation and emergency response plans and programs.

Policies

3.1.1 Coordination. Coordinate with each other, with other jurisdictions and with appropriate private and public entities prior to a disaster and to the greatest extent feasible within the resources available, to plan and establish disaster recovery programs and procedures which will enable cooperative ventures, reduce potential conflicts, minimize duplication and maximize the available funds and resources to the greatest mutual benefit following a disaster. [All EOO recovery programs involving cooperative efforts between entities implement this policy.]

3.1.2 Health/safety/environment. Develop and establish procedures for identification and abatement of physical and health hazards which may result from a disaster. Provisions shall include measures for protecting workers, the public and the environment from contamination or other health and safety hazards associated with abatement, repair and reconstruction programs. [All EOO hazard mitigation, response, recovery programs involving identification and mitigation of release of hazardous materials and protection of the public and emergency personnel from hazardous materials implement this policy.]

3.1.3 Historic/cultural. Develop procedures which will encourage the protection and preservation of City-designated historic and cultural resources to the greatest extent feasible within the resources available during disaster recovery. [All EOO recovery programs that encourage protection and preservation of historic and cultural resources implement this policy.]

3.1.4 Interim services/systems. Develop and establish procedures prior to a disaster for immediate reestablishment and maintenance of damaged or interrupted essential infrastructure systems and services so as to provide communications, circulation, power, transportation, water and other necessities for movement of goods, provision of services and restoration of the economic and social life of the City and its environs pending permanent restoration of the damaged systems. [All EOO response, recovery programs involving restoration of the City's infrastructure and essential services and service systems implement this policy.]

3.1.5 Restoration. Develop and establish prior to a disaster short- and long-term procedures for securing financial and other assistance, expediting assistance and permit processing and coordinating inspection and permitting activities so as to facilitate the rapid demolition of hazards and the repair, restoration and rebuilding, to a comparable or a better condition, those parts of the private and public sectors which were damaged or disrupted as a result of the disaster. [All EOO recovery programs involving financial planning, permit expediting and legislative and administrative actions to facilitate post-disaster recovery implement this policy.]

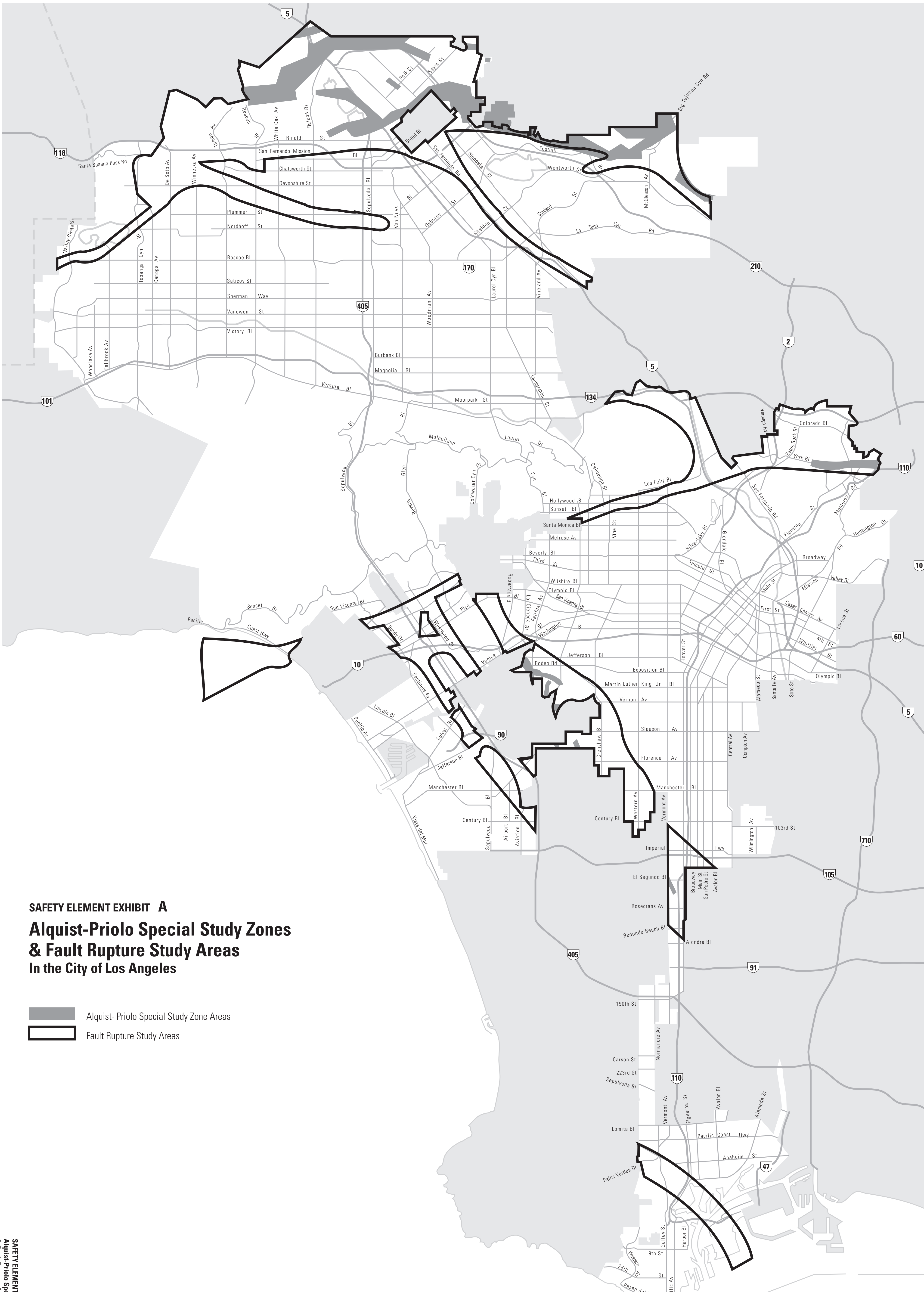
CHAPTER IV - IMPLEMENTATION

An Implementation program is an action, procedure, program or technique that carries out general plan policy. The Emergency Operations Organization (EOO) is the program that implements the Safety Element. The EOO is a City department comprised of all City agencies, pursuant to City Administrative Code, Division 8, Chapter 3. The Administrative Code, EOO Master Plan and associated EOO plans establish the chain of command, protocols and programs for integrating all of the City's emergency operations into one unified operation. Each City agency in turn has operational protocols, as well as plans and programs, to implement EOO protocols and programs. A particular emergency or mitigation triggers a particular set of protocols which are addressed by implementing plans and programs. The City's emergency operations program encompasses all of these protocols, plans and programs. Therefore, its programs are not contained in one comprehensive document. The Safety Element goals, objectives and policies are broadly stated to reflect the comprehensive scope of the EOO.

As a covered entity under Title II of the Americans with Disabilities Act, the City of Los Angeles does not discriminate on the basis of disability, and upon request, will provide reasonable accomodation to ensure equal access to its programs, services and activities.

EXHIBITS

SAFETY ELEMENT EXHIBIT A
Alquist-Priolo Special Study Zones
& Fault Rupture Study Areas



In the City of Los Angeles

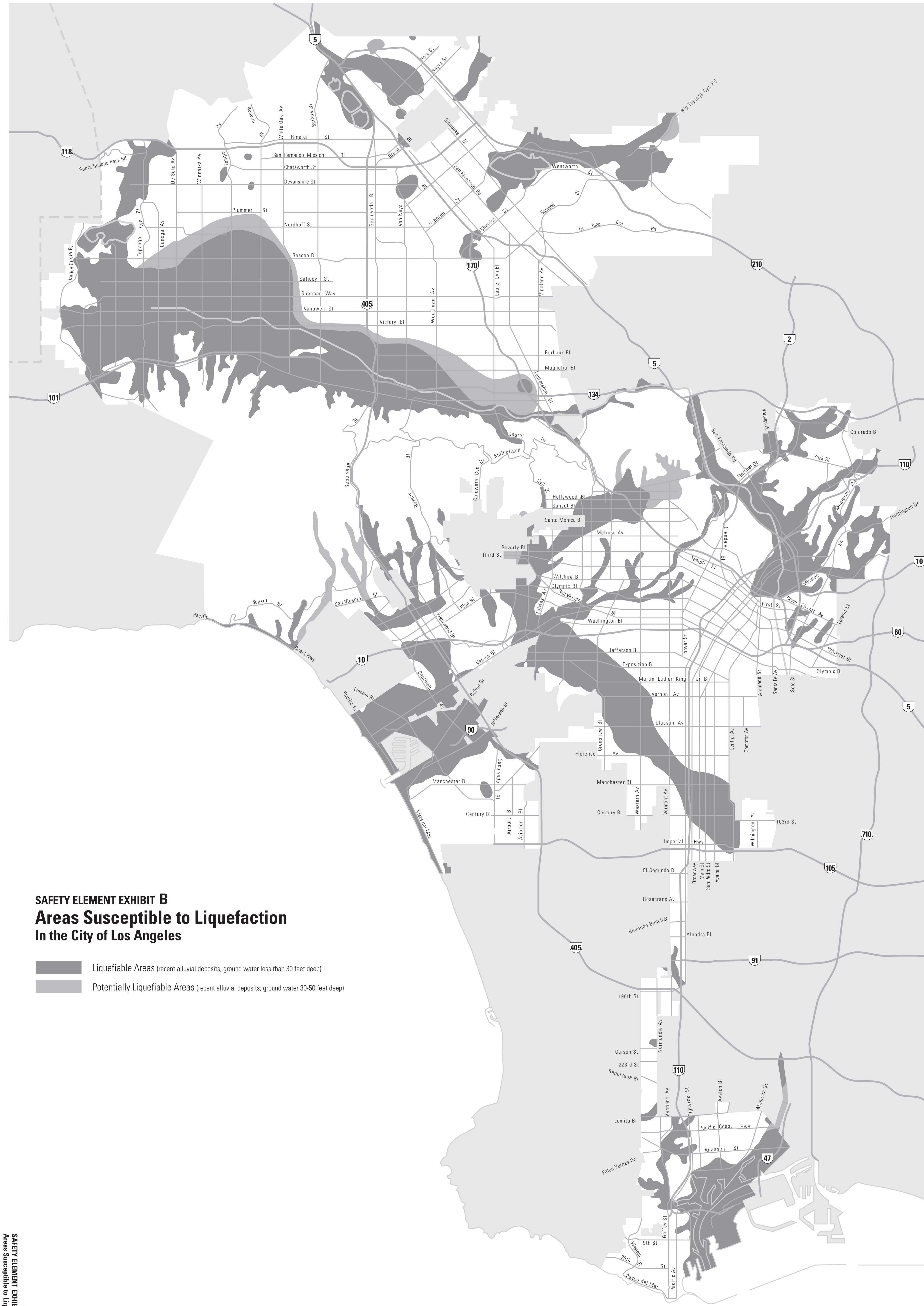
SAFETY ELEMENT EXHIBIT A
Alquist-Priolo Special Study Zones
& Fault Rupture Special Study Areas

NOTES

The Safety Element seismic and landslide exhibits, along with any official geologic or seismic hazard maps prepared by the State Geologist and any other potential hazard areas identified by the City Building Safety Department are used in determining if additional soils and geology reports should be prepared to help assess potential hazards and mitigations, as a part of the development permit process.

Sources: California Environmental Impact Report, Framework Element, Los Angeles City General Plan, May 1995; California Environmental Quality Act of 1970 (CEQA), Public Resources Code 21000 *et. seq.* as amended 1992, Alquist-Priolo Special Study Zone Act, Public Resources Code 2621-2630 and 2690-2699.6 as amended 1993, State of California Special Studies Zone maps for the following USGS quadrangles: Oat Mountain (1-1-76) San Fernando (1-1-79), Sunland (1-1-79), Burbank (1-1-79), Beverly Hills (6-1-86), Hollywood (6-1-86), Los Angeles (1-1-77), Inglewood (6-1-86), Torrance (6-1-86), Long Beach (6-1-86), as prepared by the State Geologist pursuant to the Alquist-Priolo Special Study Zones Act, City of Los Angeles Seismic Safety Plan Element of the General Plan Council file 74-3401, September 10, 1975.

Prepared by the General Plan Framework Section • City of Los Angeles Planning Department • Citywide Graphics • March 1994 • Council File No. 89-2104



SAFETY ELEMENT EXHIBIT B

Areas Susceptible to Liquefaction

In the City of Los Angeles

- Liquefiable Areas (recent alluvial deposits; ground water less than 30 feet deep)
- Potentially Liquefiable Areas (recent alluvial deposits; ground water 30-50 feet deep)

NOTES

The Safety Element seismic and landslide exhibits, along with any official geologic or seismic hazard maps prepared by the State Geologist and any other potential hazard areas identified by the City Building Safety Department are used in determining if additional soils and geology reports should be prepared to help assess potential hazards and mitigations, as a part of the development permit process.

Sources: Environmental Impact report, Framework Element, Los Angeles City General Plan, May 1995; County of Los Angeles, General Plan Safety Element Technical Appendix Vol. 2 plate 4 "Liquefaction Susceptibility", January 1990.

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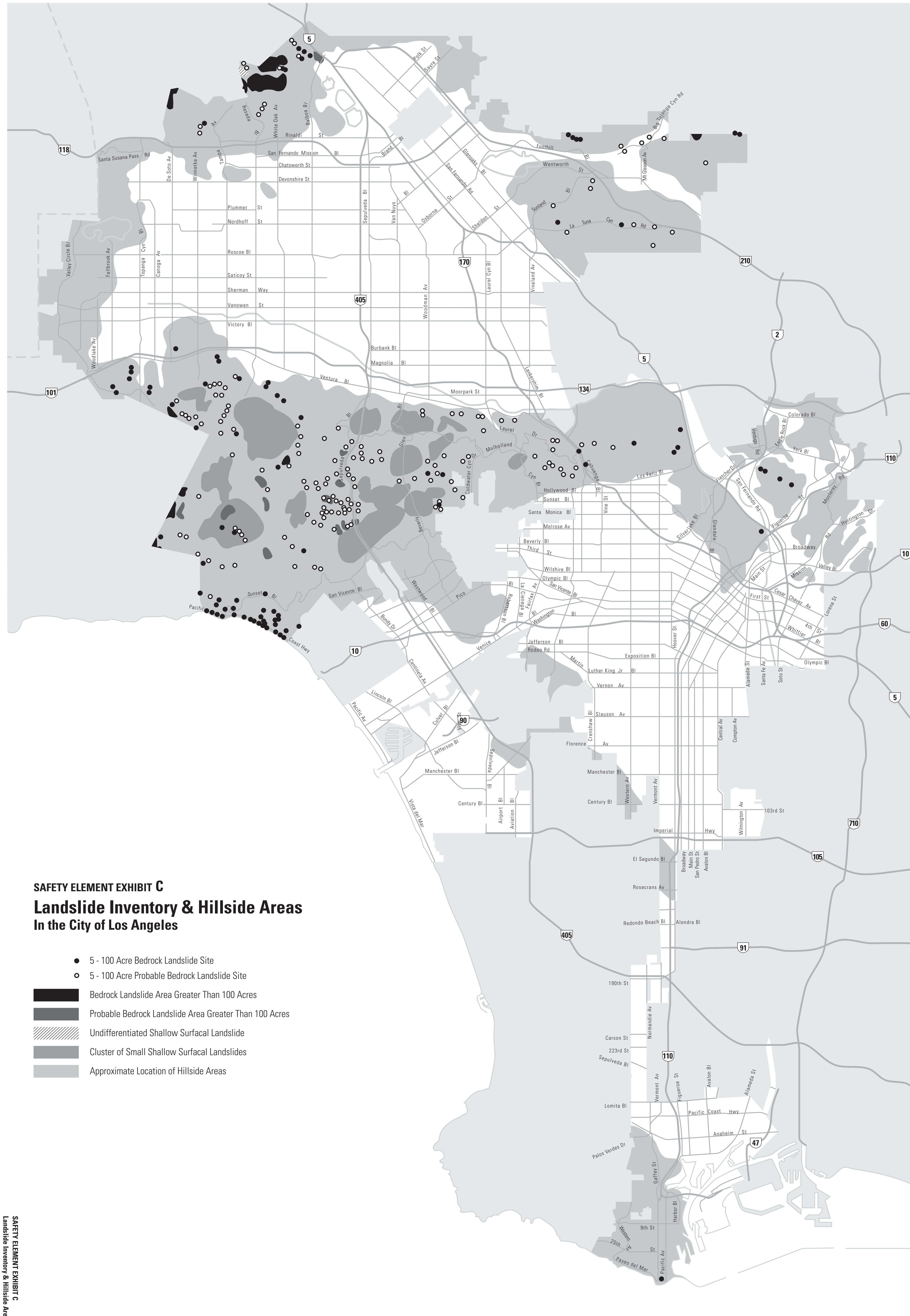

SAFETY ELEMENT EXHIBIT **C**

Landslide Inventory & Hillside Areas

In the City of Los Angeles

- ● 5 - 100 Acre Bedrock Landslide Site
- ○ 5 - 100 Acre Probable Bedrock Landslide Site
- Bedrock Landslide Area Greater Than 100 Acres
- Probable Bedrock Landslide Area Greater Than 100 Acres
- Undifferentiated Shallow Surfacal Landslide
- Cluster of Small Shallow Surfacal Landslides
- Approximate Location of Hillside Areas

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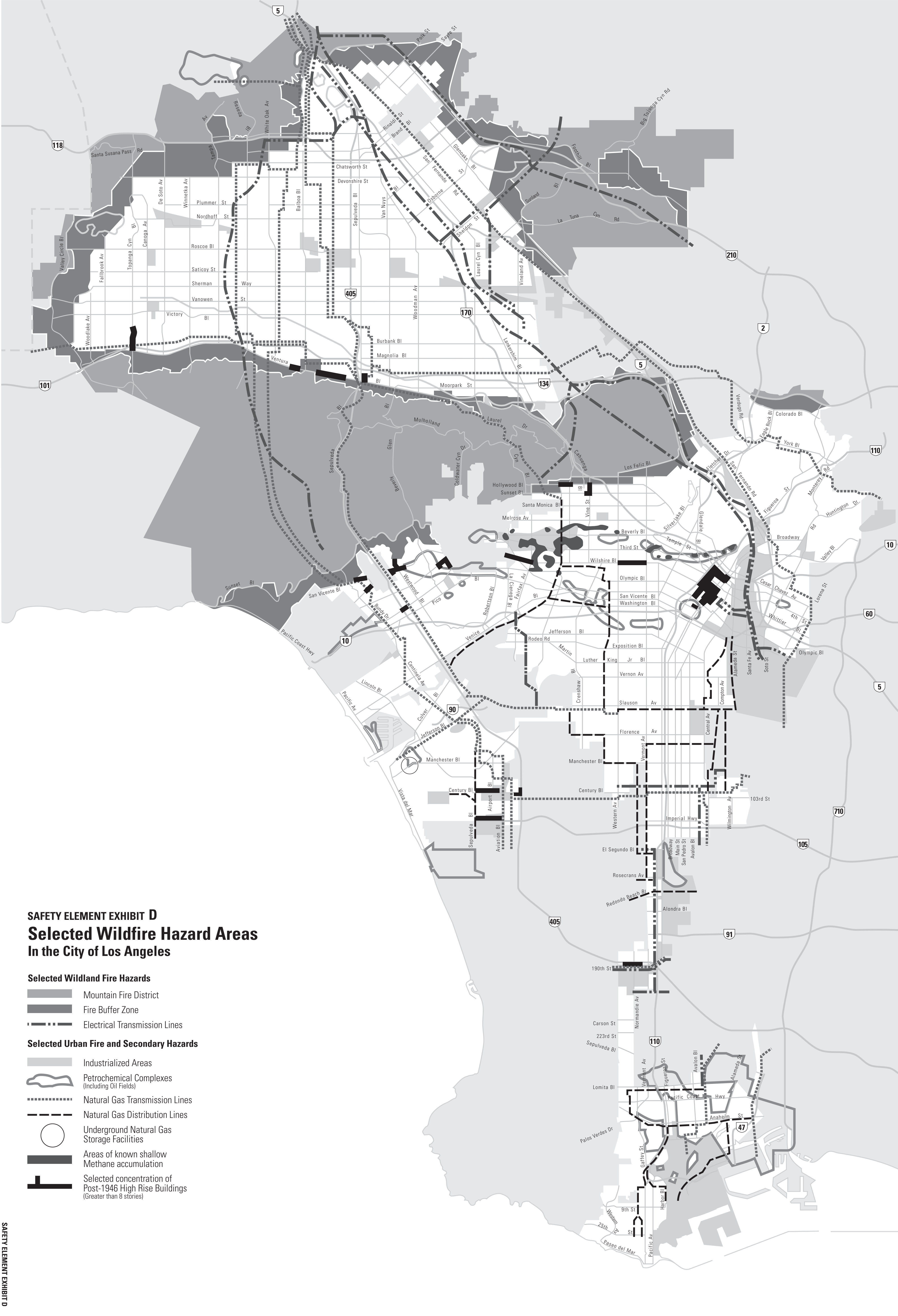
NOTES

The Safety Element seismic and landslide exhibits, along with any official geologic or seismic hazard maps prepared by the State Geologist and any other potential hazard areas identified by the City Building Safety Department are used in determining if additional soils and geology reports should be prepared to help assess potential hazards and mitigations, as a part of the development permit process.

Sources: Environmental Impact Report, Framework Element, Los Angeles City General Plan, May 1995; County of Los Angeles, General Plan *Safety Element Technical Appendix Vol. 2 Plate 5* "Landslide inventory", January 1990; County of Los Angeles, *General Plan Safety Element Technical Appendix (Vol.1)*, "Hazard Reduction in Los Angeles County," December 1990 California Environmental Quality Act of 1970 (CEQA) with guideline, Public Resources Code Section 21000 *et. seq.*, as amended 1992; California Government Code Section 6530(g), as amended; City of Los Angeles, Planning and Zoning Code Section 17.05(c), as revised 10-13-93.

Prepared by the General Plan Framework Section • City of Los Angeles Planning Department • Citywide Graphics • June, 1994 • Council File No. 89-2104



SAFETY ELEMENT EXHIBIT D

Selected Wildfire Hazard Areas

In the City of Los Angeles

Selected Wildland Fire Hazards

- Mountain Fire District
- Fire Buffer Zone
- Electrical Transmission Lines

Selected Urban Fire and Secondary Hazards

- Industrialized Areas
- Petrochemical Complexes (Including Oil Fields)
- Natural Gas Transmission Lines
- Natural Gas Distribution Lines
- Underground Natural Gas Storage Facilities
- Areas of known shallow Methane accumulation
- Selected concentration of Post-1946 High Rise Buildings (Greater than 8 stories)

SAFETY ELEMENT EXHIBIT D
Selected Wildfire Hazard Areas

NOTES

1. Mountain Fire Districts and Buffer Zones (Los Angeles City Fire Code Section 57.25) have been substituted for the "Fire Zone 4" and "Additional Areas of High Fire Hazard" designations shown on the County Safety Element Appendix exhibit.
2. Industrial zones are used to represent industrialized areas. Industrialized areas can be correlated with greater risk of public exposure to atmospheric releases of hazardous materials and flammable or explosive materials.
3. This plate does not show all fire hazards, nor does it intend to designate their relative risk. It should be used for general planning purpose only.

Source: LA County Safety Element Technical Appendix, Plate 7, December 1990. , City of Los Angeles Fire Department (See note No. 1) and Exhibit H

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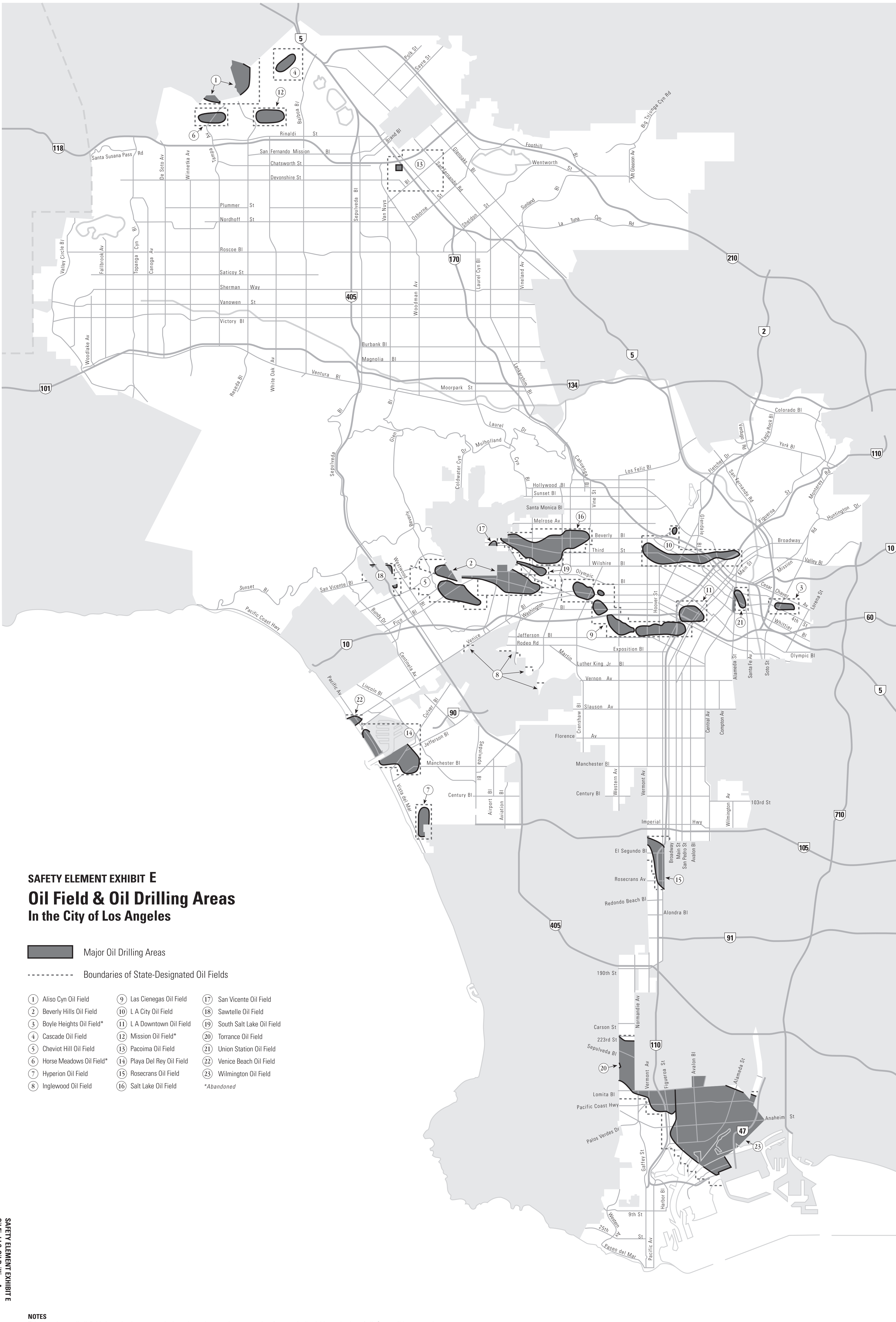

SAFETY ELEMENT EXHIBIT E

Oil Field & Oil Drilling Areas
In the City of Los Angeles

Major Oil Drilling Areas

Boundaries of State-Designated Oil Fields

1. Aliso Cyn Oil Field
2. Beverly Hills Oil Field
3. Boyle Heights Oil Field*
4. Cascade Oil Field
5. Cheviot Hill Oil Field
6. Horse Meadows Oil Field*
7. Hyperion Oil Field
8. Inglewood Oil Field
9. Las Cienegas Oil Field
10. L A City Oil Field
11. L A Downtown Oil Field
12. Mission Oil Field*
13. Pacoima Oil Field
14. Playa Del Rey Oil Field
15. Rosecrans Oil Field
16. Salt Lake Oil Field
17. San Vicente Oil Field
18. Sawtelle Oil Field
19. South Salt Lake Oil Field
20. Torrance Oil Field
21. Union Station Oil Field
22. Venice Beach Oil Field
23. Wilmington Oil Field

**Abandoned*

NOTES

This map shows all oil fields know by the state geologist to have shown at least 6 months of economically viable production of oil. State wildcat maps show that exploratory wells have been drilled throughout the city.

Sources: Environmental Impact Report, Framework Element, Los Angeles City General Plan, May 1995; California Department of Conservation Division of Oil and Gas (DOG), Publication No. TR31, Land Use Planning in Urban Oil Producing Areas, 1988: DOG, Publication No. PRC 04, California Code of Regulations, Title 14 "Natural Resources" Section 1681 *et. seq.*, as amended February 1993; DOG, Publication No. PRCO1, California Public Resources Code, Division 3"Oil and Gas", Sec. 3000 *et. seq.*, as amended July 1993; Division of Oil and Gas and Geothermal Resources, Construction project site review and well abandonment procedure (Brochure), as amended February 1994; City of Los Angeles Planning Department, interviews with DOG Long Beach office staff Engineers, 1994; California Environmental Quality Act of 1970 (CEQA) including guidelines, PRC SEC. 21000 *et. seq.*, as amended 1992.

Prepared by the General Plan Framework Section • City of Los Angeles Planning Department • Citywide Graphics • May, 1994 • Council File No. 89-2104

SAFETY ELEMENT EXHIBIT F

100-Year & 500-Year Flood Plains

In the City of Los Angeles

100-Year Flood Plain Areas

500-Year Flood Plain Areas

SAFETY ELEMENT EXHIBIT F
100-Year & 500-Year Flood Plains

NOTES

1. A 500-Year flood will also flood 100-Year flood plains.
2. A 100-Year flood is a flood which results from a severe rainstorm with a probability of occuring approximately once every 100 years.
3. A 500-Year flood is a flood which results from a severe rainstorm with a probability of occuring once every 500 years.
4. Flood plains shown on the map reflect Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) currently in effect and Preliminary FIRM maps showing increases in expected flooding along the Los Angeles River and Dominguez Channel. Flood plains are now larger due to increased urbanization of the Los Angeles River Basin.

Sources: Environmental Impact Report, Framework Element, Los Angeles City General Plan, May 1995; Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps; FEMA Preliminary Flood Insurance Rate Maps; California Evironmental Quality Act of 1970 (CEQA), Public Resources Code Section 21000 et. seq., as amended 1992; California Government Code Section 65302 as amended 1993.

Prepared by the General Plan Framework Section • City of Los Angeles Planning Department • Citywide Graphics • March, 1994 • Council File No. 89-2104

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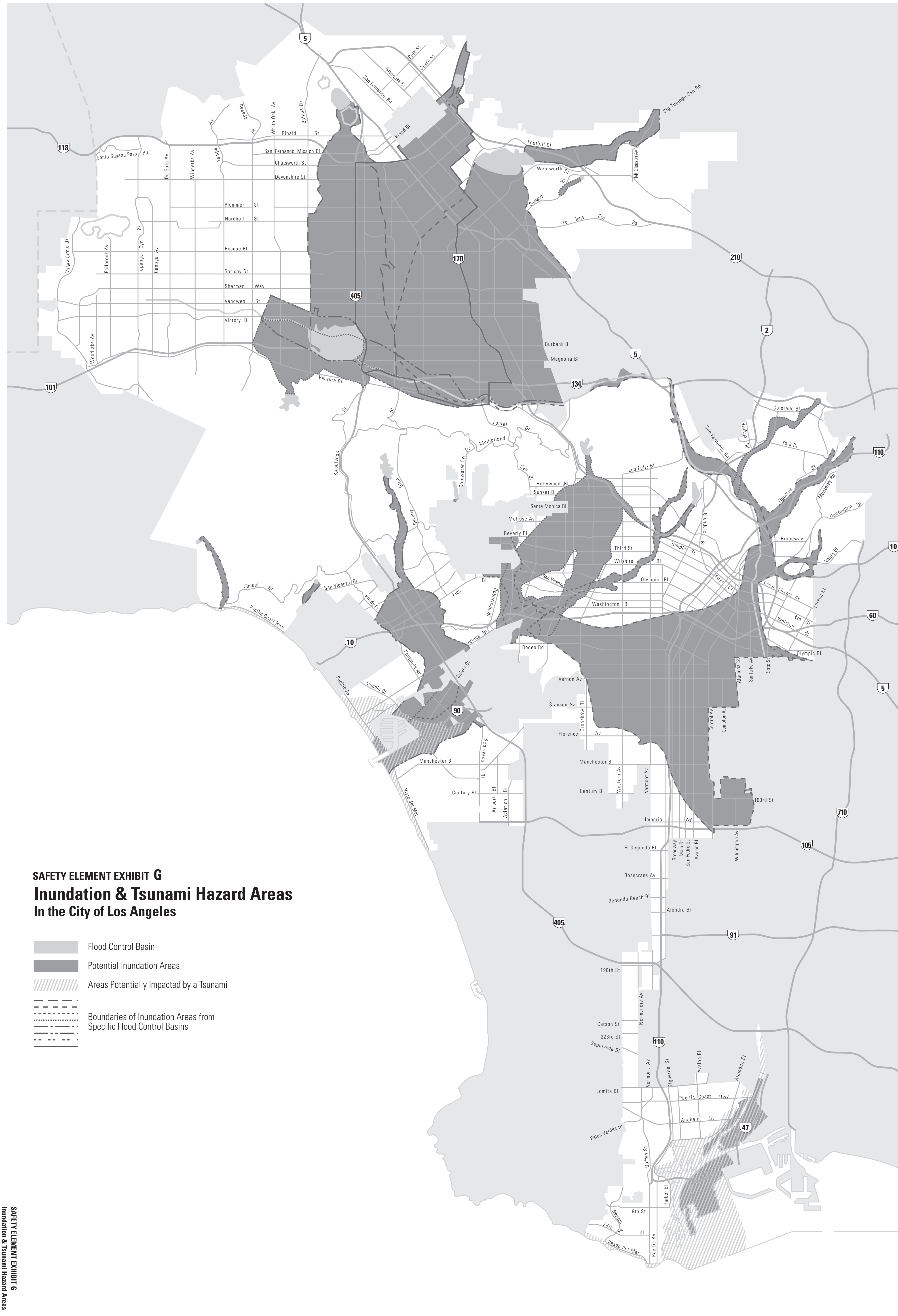

SAFETY ELEMENT EXHIBIT G

Inundation & Tsunami Hazard Areas

In the City of Los Angeles

- Flood Control Basin
- Potential Inundation Areas
- Areas Potentially Impacted by a Tsunami
- Boundaries of Inundation Areas from Specific Flood Control Basins

Sources: Environmental Impact Report, Framework Element, Los Angeles City General Plan, May 1995; Technical Appendix to the Safety Element of the Los Angeles County General Plan Hazard Reducation in Los Angeles County, Volume 2, Plate 6, "Flood and Inundation Hazards" January 1990; California Environmental Quality Act of 1970 (CEQA), Public Resources Code Section 21000 *et. seq.* with guidelines as amended, 1992; California Government Code Title 7 chapter 3, article 5 section 65302(g), as amended 1993.

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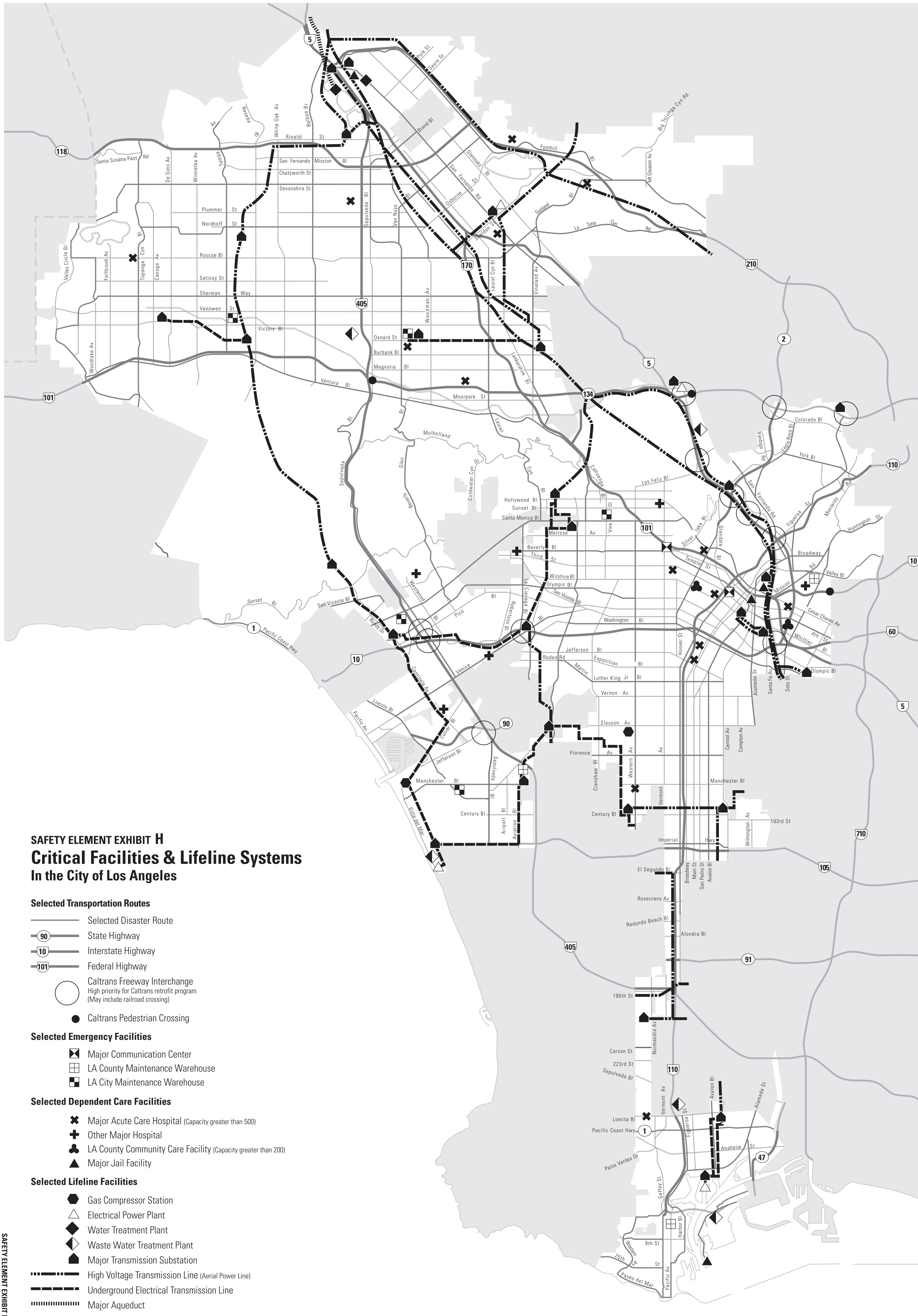

SAFETY ELEMENT EXHIBIT H

Critical Facilities & Lifeline Systems

In the City of Los Angeles

Selected Transportation Routes

- Selected Disaster Route
- (90) State Highway
- (10) Interstate Highway
- (101) Federal Highway
- Caltrans Freeway Interchange — High priority for Caltrans retrofit program (May include railroad crossing)
- Caltrans Pedestrian Crossing

Selected Emergency Facilities

- Major Communication Center
- LA County Maintenance Warehouse
- LA City Maintenance Warehouse

Selected Dependent Care Facilities

- Major Acute Care Hospital (Capacity greater than 500)
- Other Major Hospital
- LA County Community Care Facility (Capacity greater than 200)
- Major Jail Facility

Selected Lifeline Facilities

- Gas Compressor Station
- Electrical Power Plant
- Water Treatment Plant
- Waste Water Treatment Plant
- Major Transmission Substation
- High Voltage Transmission Line (Aerial Power Line)
- Underground Electrical Transmission Line
- Major Aqueduct

NOTES

1. This map is intended to present the general distribution of community elements vulnerable to damages from a variety of hazards. In order to preserve map clarity, all important critical facilities and lifelines are not shown.
2. Disaster routes function as primary thoroughfares for movement of emergency response traffic and access to critical facilities. Immediate emergency debris clearance and road/bridge repairs for short-term emergency operations will be emphasized along these routes.
3. The selected disaster routes also provide a plan for interjurisdictional road reconstruction and rebuilding following a major disaster.
4. The compilation of selected lifeline facilities relied heavily upon California Division of Mines and Geology, Earthquake Scenario Reports, Special Publications 60 and 99.
5. This map is intended for general land use and disaster planning purposes only.

Source: LA County Safety Element Technical Appendix, Plate 8, December 1990 & General Plan Framework EIR.

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