SEISMIC HAZARD ZONE REPORT 05

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

1997

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methodology and sources of information used to prepare the Seismic Hazard Zone Map for the Oat Mountain 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 about 62 square miles at a scale of 1 inch = 2,000 feet.

The center of the Oat Mountain Quadrangle lies about 26 miles northwest of the Los Angeles Civic Center. Several suburban communities, all part of the City of Los Angeles, including Chatsworth, Northridge, and Granada Hills, lie near the southern edge of the quadrangle in the northern San Fernando Valley. To the north, the eastern half of the Santa Susana Mountains covers much of the rest of the quadrangle, except in the northeastern corner where part of the City of Santa Clarita is located. Interstate Highway 5 extends from San Fernando Pass, on the eastern edge of the quadrangle, northwesterly through the northeastern quarter of the quadrangle. Northeast of Highway 5, the hills become progressively lower and more subdued as they approach the nearly level terrain at the southern edge of the Santa Clarita Valley. Residential and commercial development covers the floor of the San Fernando Valley, is expanding into the hills to the north, between Limekiln and Bee canyons and is also rapidly spreading southward along stream bottoms and low hills in the City of Santa Clarita.

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 Oat Mountain Quadrangle the liquefaction zones are located in the Chatsworth and northern Granada Hills portions of the San Fernando Valley and the bottoms of canyons. The mountainous terrain that dominates the quadrangle contains widespread earthquake-induced landslide zones. The combination of dissected mountains, weak rocks, and abundant existing landslide complexes results in earthquake-induced landslide zones that cover about 39% of the quadrangle.

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://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

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 Oat Mountain 7.5-minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By
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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 Oat Mountain 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 Oat Mountain 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 Oat Mountain 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 Oat Mountain Quadrangle covers an area of about 62 square miles in western Los Angeles County. Several suburban communities, all part of the City of Los Angeles, including Chatsworth, Northridge, and Granada Hills, lie near the southern edge of the quadrangle in the northern San Fernando Valley. North of the valley, the eastern half of the Santa Susana Mountains covers much of the remainder of the quadrangle, except for the northeastern corner, which contains a portion of the City of Santa Clarita. Canyons within the mountains trend southward toward the San Fernando Valley, or northward toward the Santa Clara River drainage in the Newhall area. The center of the area is 26 miles northwest of downtown Los Angeles.

Oat Mountain is a broad ridge that trends northwesterly across the center of the quadrangle and dominates the terrain in the area. The ridgeline of Oat Mountain generally ranges between 3000 and 3500 feet in elevation. The highest elevation, 3747 feet, occurs at the western end of the Oat Mountain ridgeline. The south flank of Oat Mountain displays highly broken and irregular topography, in terrain that overlies the Santa Susana thrust fault and other faults located between the ridgetop and the north edge of the San Fernando Valley. The north flank of Oat Mountain and the succession of northwest trending ridges extending to the north have not been as extensively disrupted by faulting, so that the terrain is more regular. Ridges and drainage courses are narrow, with long steep slopes between ridgetop and stream bottoms.

Several large streams draining the south flank of Oat Mountain have eroded steep-walled canyons into the hills and alluvial fans along the northern edge of the San Fernando Valley. The valley floor slopes gently toward the south, from an elevation of about 1100 feet at the base of the hills, to about 900 feet at the south edge of the quadrangle.

Interstate Highway 5 extends from San Fernando Pass, on the eastern edge of the quadrangle, northwesterly through the northeastern quarter of the quadrangle. Northeast of Highway 5, the hills become progressively lower and more subdued as they approach the nearly level terrain at the southern edge of the Santa Clarita Valley.

Residential and commercial development covers the floor of the San Fernando Valley, and is expanding into the hills along northern edge of the valley, between Limekiln and Bee canyons in the southeast quarter of the quadrangle. Residential development in the City of Santa Clarita is also rapidly expanding southward along stream bottoms and low hills in the northeast quarter of the quadrangle.

GEOLOGY

Structural Geology and Depositional Setting

The San Fernando Valley is an east-trending structural trough within the Transverse Ranges geologic province of southern California. The Santa Susana Mountains that bound it to the north are an actively deforming anticlinal range with thrust faults within it. As the range has risen and deformed, the San Fernando Valley has subsided and filled with sediment.

The northern portion of the San Fernando Valley on the Oat Mountain quadrangle has received sediment from small drainage areas in the Santa Susana Mountains. These small drainage courses have deposited their sediment in the form of channel deposits, alluvial fans, and floodplain deposits in the valley. Composition of these deposits is dependent on the source area drained by the streams. Streams with source areas in the Santa Susana Mountains have sandstone and siltstone strata of Cretaceous through Pleistocene age in their drainage basins. The deposits created by these streams, consequently, are composed of silty or sandy alluvium.

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Late Quaternary geologic units in the San Fernando Valley area were completely re-mapped for this study and a concurrent study by engineering geologist Chris Hitchcock of William Lettis and Associates (Hitchcock and Wills, 1998; 2000). Lettis and Associates received a grant from the National Science Foundation (NSF) to study the activity of the Northridge Hills uplift. As part of the research for this study, Hitchcock mapped Quaternary surficial units by interpretation of their geomorphic expression on aerial photographs and topographic maps. The primary source for this work was 1938 aerial photographs taken by the U.S. Department of Agriculture (USDA). His interpretations were checked and extended for this study using 1952 U.S.D.A. aerial photos, 1920's topographic maps and subsurface data. The resulting map (Hitchcock and Wills, 2000) represents a cooperative effort to depict the Quaternary geology of the San Fernando Valley combining surficial geomorphic mapping and information about subsurface soils engineering properties. This new mapping did not include fluvial and alluvial deposits in the northerly part of the Oat Mountain Quadrangle where streams flow into the Santa Clara River. The portion of this map that covers the Oat Mountain Quadrangle is reproduced as Plate 1.1.

In preparing the Quaternary geologic map for the San Fernando Valley, geologic maps prepared by Evans and Miller (1978), Saul (1979), Tinsley and others (1985), Yerkes and Campbell (1993) and Dibblee (1992) were referred to. We began with the map of Yerkes and Campbell (1993) as a file in the DMG Geographic Information System. The Quaternary geology shown on the map of Yerkes and Campbell (1993) was itself compiled from earlier works by Evans and Miller (1978) and Saul (1979), with some modifications, possibly based on mapping by Tinsley and others (1985). For this study, we did not review or revise the mapping of bedrock units by Yerkes and Campbell (1993), except at the contacts between bedrock and Quaternary units. Within the San Fernando Valley, mapping of Quaternary units by Hitchcock (and for this study) was used to refine and substantially revise this mapping. For this map (Plate 1.1), geologic units were defined based on geomorphic expression of Quaternary units (interpreted from aerial photographs and earlier editions of U.S. Geological Survey topographic maps) and subsurface characteristics of those units (based on borehole data). The nomenclature of the Southern California Areal Mapping Project (SCAMP) (Morton and Kennedy, 1989) was applied to all Quaternary units (Table 1.1).

	Alluvial fan deposits	**Alluvial valley deposits**	
Active	Qf- active fan	Qa- active depositional basin	
	Qw- active wash		Holocene?
Young	Qyf2	Qyt	
	Qyf1		
Old	Qof2	Qt	
	Qof1		Pleistocene?
Very old	Qvof2	Qvoa2*	
		Qvoa1*	

*may have been alluvial fan, depositional form not preserved

Table 1.1. Units of the Southern California Areal Mapping Project (SCAMP) Nomenclature Used in the San Fernando Valley.

The Quaternary geologic map (Plate 1.1) shows that the oldest alluvial units in the San Fernando Valley are found within the Northridge Hills and on the south flank of the Santa Susana Mountains. The Saugus Formation (Qs, Qsm, and Qsu, not shown on Plate 1.1), a Plio-Pleistocene alluvial unit makes up much of the south flank of the Santa Susana Mountains and is exposed in the core of anticlinal hills along the Northridge Hills uplift.

Overlying Saugus Formation in the Northridge Hills are very old alluvial deposits (Qvoa1 and Qvof2). These deposits are uplifted, deformed, have red (old) soils and are typically dense to very dense. The older unit, Qvoa1, is predominantly silt and clay and shows no trace of its original depositional geomorphology. The younger unit, Qvof2, although similarly uplifted, appears to be part of an alluvial fan that extended over the Northridge Hills before uplift cut it off from its source.

Overlying very old alluvial deposits in the Northridge Hills are deposits that formed as alluvial fans from the Santa Susana Mountains (Qof1). These deposits are composed of sand, silt, and gravel and form recognizable alluvial fans. The fan surfaces are no longer active because continuing deformation has either elevated them above the area of deposition or because they have been buried by later alluvium. Older alluvium is distinguished from younger alluvium by being uplifted and usually incised by younger drainage courses and by having relatively even tonal patterns on pre-development aerial photographs. Younger alluvium, in contrast, typically has a braided stream tonal pattern even when those stream channels have no geomorphic expression. Qof1 consists of small alluvial fans along the south side of the Santa Susana Mountains. Along the southern front of the Santa Susana Mountains, all major streams are incised into the Qof1 surface. At the Northridge Hills, the largest stream, Limekiln Wash, has incised completely through the hills, leaving remnants of the Qof1 surface as terraces. Smaller drainage courses, especially Wilbur Wash and Aliso Wash, have apparently been blocked by the Northridge Hills, causing deposition of younger alluvium on top of Qof1. The Qof1 surface re-emerges from beneath these younger sediments in the Northridge Hills. It is warped over the hills and buried by younger sediments again on the south side.

The streams that cross the Northridge Hills, as well as others from the south and west, have built alluvial fans into the main San Fernando Valley basin south of the hills. These alluvial fans can be subdivided into young (Qyf1 and Qyf2) and active (Qf) fan deposits on the basis of geomorphology. The most significant fans are discussed below.

Bull Canyon Fan

Bull Creek, which has a small (about 1 square mile) drainage basin in the Santa Susana Mountains extends into the San Fernando Valley and through the Northridge Hills at Bull Creek gap. North of Bull Creek gap, Bull Creek has deposited young alluvium (Qyf2) in a fan with its head near the mountain front. Younger, actively accumulating alluvium appears to be deposited south of the Oat Mountain Quadrangle in a series of young alluvial fans in the adjacent Canoga Park and Van Nuys quadrangles.

Wilbur and Aliso Canyon Fans

Wilbur Wash and Aliso Wash have relatively small drainage basins in the Santa Susana Mountains (about 1/2 and 2 square miles, respectively). They have deposited fans (Qyf2) consisting of clay, silty sand, and silt, which cover the older fan deposits (Qof1) on the north side of the Northridge Hills. These fans appear to be ponded against the north side of the Northridge Hills. Wilbur Wash has deposited a fan with its apex at the mountain front, but the Aliso Canyon fan has its apex about 2000 feet south of the mountain front. The apex of the fan south of the mountain front suggests southward tilting of this portion of the valley.

Limekiln Canyon Wash

Limekiln Canyon Wash has been able to maintain an incised channel through the Northridge Hills into the main San Fernando basin south of the hills. This is probably due to its larger drainage area (about 3 square miles) and erosive power. The apex of the Limekiln Canyon fan is on the south side of the Northridge Hills; it extends from there into the floor of the valley.

Browns Canyon Wash

Browns Canyon Wash has the largest drainage basin of the streams with source areas in the Santa Susana Mountains (about 12 square miles), but emerges from the mountains in the complex northwestern corner of the valley. Deposits of Browns Canyon alluvium have filled the Chatsworth basin, which is separated from the main San Fernando basin by the Chatsworth Fault. Browns Canyon alluvium then overflowed the Chatsworth basin and built an alluvial fan south of the Northridge Hills onto the floor of the San Fernando Valley. The main alluvial fan has its apex where the trend of the main Northridge Hills uplift crosses Browns Canyon wash, suggesting tectonic control of the young sedimentation. The apex of active fan, however, is once again well south of the main fan apex suggesting southward tilting of the whole San Fernando basin.

In the northern portion of the Oat Mountain Quadrangle, the alluvial valleys are within the Santa Clara River basin and are mapped as undifferentiated alluvium (Qal).

ENGINEERING GEOLOGY

The geologic units described above were primarily mapped from their surface expression, especially geomorphology as shown on aerial photos and old topographic maps. The geomorphic mapping was compared with the subsurface properties described in over 200 borehole logs in the study area. Subsurface data used for this study includes the database compiled by John Tinsley for previous liquefaction studies (Tinsley and Fumal, 1985; Tinsley and others, 1985), a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1996), and additional data collected for this study. Subsurface data were collected for this study at Caltrans, the California Department of Water Resources, DMG files of seismic reports for hospital and school sites, the Regional Water Quality Control Board and from Law Crandall, Inc., Leighton and Associates, Inc, and Woodward-Clyde Consultants. In general, the data gathered for geotechnical studies appear to be well distributed areally and provide reliable information on water levels. Geotechnical data, particularly SPT blow counts, from environmental studies are sometimes less reliable however, due to non-standard equipment and incomplete reporting of procedures. Water-well logs from the Department of Water Resources tend to have very sketchy lithologic descriptions and generally unreliable reports of shallow unconfined water levels. Apparently, water-well drillers may note the level of productive water, ignoring shallower perched water or water in less permeable layers.

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 1 atmosphere (approximately 1 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 $(N_1)_{60}$.

Data from previous databases and additional borehole logs were entered into the DMG GIS database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and outlining of areas of similar soils.

In most cases, the subsurface data allow mapping of different alluvial fans. Different generations of alluvium on the same fan, which are very apparent from the geomorphology, are not distinguishable from the subsurface data.

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized, but give the most commonly encountered characteristics of the units (see Table 1.2).

Saugus Formation (Qs, Qsm, Qsu)

The Plio-Pleistocene Saugus Formation is an alluvial unit and often cannot readily be distinguished from younger overlying alluvium in borehole logs. In the few boreholes where we can be sure Saugus Formation was encountered, it is described as "sandstone." In others, dense or very dense sand may be Saugus Formation but also could be old or very old alluvium.

Very old alluvium (Qvoa1, Qvof2)

Very old alluvium, mapped in the Northridge Hills, is represented in the subsurface data by several boreholes in unit Qvoa1. The material in these boreholes is dense to very dense silt, and very stiff to hard clay with minor dense sand.

Older alluvium (Qof1)

In the subsurface, Qof1 consists of silt and silty sand with lesser sand, gravel and clay layers. Sand layers are dense to very dense. Individual layers can rarely be traced from well to well, reflecting the lenticular layering typical of an alluvial fan deposit.

Younger alluvium (Qyf1, Qyf2, Qyt, Qf, Qw)

Within an alluvial fan, the different generations of younger alluvium can be distinguished by their geomorphic relationships. In the subsurface, it is not possible to distinguish among the generations of an alluvial fan. There may simply be too little difference in age among the various units, which probably range in age from mid-Holocene to historic, for any differences in density or cementation to have formed. In addition, since no geotechnical data were obtained from locally developed, thin, veneer-like, young terrace deposits adjacent to watercourses (Qyt), this unit is not included in Table 1.2.

The Aliso Canyon and Wilbur Wash fans consist of interbedded clay, silt and silty sand. SPT field N values in granular materials range from 20 to 35 suggesting medium dense to dense conditions. These values are from only three boreholes at one site, however, the unit may have looser materials in it. Unfortunately, none of the other boreholes in the Aliso Canyon and Wilbur Wash fans had penetration resistance data.

The Limekiln Canyon fan consists of interbedded clay and sand, with minor silt. Granular deposits are described as loose to medium dense with SPT field N values generally ranging from 3 to 12.

Browns Canyon alluvium consists of loose to moderately dense sand and silty sand layers with interbeds of silt and clay. Typical SPT field N values range from 10 to 25 with a few between 5 and 10.

Undifferentiated alluvium in the Santa Clarita Area (Qal)

In the Santa Clarita area, the main trunk and tributary upland alluvial valleys of Gavin Canyon and Newhall Creek Valley contain undifferentiated fluvial and alluvial deposits. The deposits generally consist of complexly interbedded, light-brown, brown and gray-brown, silty or clayey fine to medium or fine to coarse sand units, with minor scattered gravel and/or cobble layers. Also found in the undifferentiated deposits are light-brown, brown and gray-brown, poorly graded, fine to medium or medium to coarse gravelly sand layers, and thick to thin, discontinuous interbeds of brown sandy silt. The silty sands are generally described as medium compact, medium dense to dense. Approximately half of the SPT field N values in the silty sands are less than 30, and approximately half are greater than 30, with some SPT field N values grater than 50 blows. Moisture contents in the silty sands and sands are generally less than 10%. Dry unit weights are generally about 100 to 120 pcf in the silty sands and unmeasured in the sands. The density of the silts is not described, although the very few SPT field N values identified were generally between 5 and 20. Moisture contents are unmeasured. Based on the age and depositional environment of these deposits the sands in this unit are interpreted as being loose to medium dense.

Artificial fill (af)

Artificial fill on the Oat Mountain Quadrangle consists of engineered fill for freeways and waste landfills. The dam and freeway fills are shown on the map of Yerkes and Campbell (1993) and were not modified. Because the engineered fills are too thin to affect the liquefaction hazard, no effort was made of determine their subsurface characteristics.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Qal, undifferentiated alluvium, (Santa Clarita area)	sandy, silty	loose-moderately dense	high, locally moderate
Qw, stream channels	sandy, silty sand	loose-moderately dense	high
Qf, active alluvial fans	silty sand, sand, minor clay	loose-moderately dense	high
Qyf2, Younger alluvial fans	silty sand, sand, minor clay	loose-moderately dense	high
Qyf1, young alluvial fan	silty sand, sand, minor clay	loose-moderately dense	high
Qof1, older alluvial fan	sand & gravel	moderately dense	low, locally moderate
Qvoa1, very old alluvium	clay-silty sand	dense-very dense	low

Table 1.2. General Geotechnical Characteristics and Liquefaction Susceptibility of Younger Quaternary Units.

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.

Ground-water conditions were investigated in the Oat Mountain 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 agencies listed in the discussion below. 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.

San Fernando Valley

The San Fernando Valley ground-water basin is a major source of domestic water for the City of Los Angeles and, as a result, has been extensively studied. The legal rights to water in the ground within the San Fernando Valley were the subject of a lawsuit by the City of Los Angeles against the City of San Fernando and other operators of water wells in the basin. The "Report of Referee" (California State Water Rights Board, 1962) contains information on the geology, soils and ground-water levels of the San Fernando Valley.

The Report of Referee shows that ground water reached its highest levels in 1944, before excessive pumping caused drawdowns throughout the basin. Management of the ground-water resources led to stabilizing of ground-water elevations in the 1960's and, in some cases, rise of ground-water elevations in the 1970's and 1980's to levels approaching those of 1944. Wells monitored by the Upper Los Angeles River Watermaster (Blevins, 1995) show that in the western San Fernando Valley, including the area covered by this report, water levels have not recovered to the levels of the 1940's.

In order to consider the historically highest groundwater level in liquefaction analysis, the 1944 groundwater elevation contours (California State Water Rights Board 1962, Plate 29) were digitized. A three-dimensional model was created from the digitized contours giving a ground-water elevation at any point on a grid. The ground-water elevation values in this grid were then subtracted from the surface elevation values from the USGS Digital Elevation Model (DEM) for the Oat Mountain Quadrangle. The difference between the surface elevation and the ground-water elevation is the ground-water depth. Subtracting the ground-water depth grid from the DEM results in a grid of ground-water depth values at any point where the grids overlapped.

The resulting grid of ground-water depth values shows several artifacts of the differences between the sources of ground-water elevation data and surface elevation data. The ground-water elevations were interpreted from relatively few measurements in water wells. The USGS DEM is a much more detailed depiction of surface elevation; it also shows man-made features such as excavations and fills that have changed the surface elevations. Most of these surface changes occurred after the ground-water levels were measured in 1944. The ground-water depth contours were smoothed and obvious artifacts removed to create the final ground-water depth map (Plate 1.2).

Shallow ground water is also shown in the Chatsworth sub-basin, where ground water is apparently ponded north of the Chatsworth fault. This fault is recognized mainly as a ground-water barrier and is poorly expressed at the surface. In the remainder of the area, ground water is apparently deep, the Report of Referee does not show ground- water contours for 1944 north of the Northridge Hills and the numerous shallow boreholes did not encounter water. Only in the area north of the Mission Hills Fault has shallow ground water been recorded, and that only as part of a detailed investigation following the Northridge earthquake (Hecker and others 1995).

Ground water is relatively shallow in all canyons in the Santa Susana Mountains, at least in areas where we have obtained records. In general, it appears that relatively shallow and impermeable bedrock underlying the canyon alluvium helps to maintain a shallow water table.

Santa Clarita Valley

The alluvial valleys in the northern portion of the Oat Mountain Quadrangle are in the Santa Clarita ground-water basin. Ground-water depth data were obtained from published ground-water investigations (Robson, 1972) that summarized ground-water conditions in the study area for the years 1945 to 1967. Also used were annual maps of the ground-water elevation contour in the alluvial valley deposits prepared by the Los Angeles County Department of Public Works, Hydraulic/Water Conservation Division (LACDPW) for the years 1945 through 1995 (LACDPW, 1995), and information contained in the collected geotechnical and environmental borehole logs.

Interpretation of data from Robson (1972) and LACDPW (1995) indicates that the shallowest recorded depth to ground water for most of the Santa Clarita Basin occurred in 1945. However, the shallowest recorded ground-water depth in the various alluvial valleys in the northern portion of the Oat Mountain Quadrangle occurred in other years. A ground-water elevation contour map of the shallowest recorded water levels for the study area was compiled from the LACDPW ground-water contour maps from various years that represented the shallowest groundwater identified in portions of the study area. In Gavin Canyon, the 1948 map was used; in the unnamed canyon east of Gavin Canyon the 1973 map was used; along Newhall Creek, the 1952 map was used; and in the canyon west of Newhall Creek, the 1955 map was used. A depth-to-ground water contour map was prepared by comparing the compiled shallowest ground-water elevations with the ground surface elevations.

Ground-water information is generally lacking in the small alluvial valleys that are tributary to Gavin Canyon, the unnamed canyon east of Gavin Canyon, and the Newhall Creek Valley. These tributary canyons merge with the main valleys either directly onto the fluvial deposits of the valley floor or onto the alluvial fans which flank the valleys. The depth to ground water for the small tributary canyons was taken as the depth to ground water identified at the mouth of the tributary canyon where the canyon merges with either the main valley or the alluvial fans.

In Gavin Canyon, the depth to ground water is less than 40 feet at the northern edge of the study area and shallows to 30 feet about 1,000 feet to the south. In the unnamed valley east of Gavin Canyon, the depth to ground water is 75 feet at the northern edge of the study area and shallows to the south to between 0 and 35 feet in most of the valley.

The depth to ground water in the Newhall Creek Valley is 75 feet at the northern edge of the study area and shallows to the south to between 0 and 35 feet in most of the valley.

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 summarized below and on Table 1.2.

Very old alluvium (Qvoa1, Qvof2)

Very old alluvium consists of dense to very dense silt and clay deposits in an area of deep ground water. Liquefaction susceptibility of this unit is low.

Old alluvium (Qof1)

Old alluvium in the Oat Mountain Quadrangle consists of moderately dense silt and silty sand. Qof1 is found north of the Northridge Hills, where ground water is deep, but extends up some canyons into the Santa Susana Mountains. North of the Mission Hills fault and in the canyons ground water is within 40 feet of the ground surface. This deposit has low liquefaction susceptibility over most of its area due to deep ground water. In areas where ground water is shallow, the unit has moderate liquefaction susceptibility.

Young alluvium (Qyf1, Qyf2, Qf, Qw, Qal)

Younger alluvium on the Oat Mountain Quadrangle consists of silty sand with sand, silt and clay. Most boreholes in these units contain loose to moderately dense sand or silty sand. Where ground water is within 40 feet of the surface, liquefaction susceptibility of these units is high.

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 Oat Mountain Quadrangle, a PGA of 0.60 g, resulting from an earthquake of magnitude 6.5, was 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 Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (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 factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. 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 related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Of the 200 geotechnical borehole logs reviewed in this study (Plate 1.2), fewer than 50 include blow-count data from SPT’s 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 2 1/2-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 (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values or using average 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 Oat Mountain Quadrangle is summarized below.

Areas of Past Liquefaction

Evidence of liquefaction was recorded in the Oat Mountain Quadrangle in the 1971 San Fernando earthquake and the 1994 Northridge earthquake. The most extensive damage due to liquefaction occurred in 1994 near Balboa Boulevard, north of Rinaldi Street, in Granada Hills (locality 1, Plate 1.1). In that area, liquefaction within early Holocene alluvium (Qyf2) led to lateral spreading and both extensional and compressional ground cracking (Holzer and others, 1996; 1999). Post-earthquake investigations showed that the Mission Hills fault, mapped just south of the area of liquefaction, might form a ground-water barrier (Hecker and others, 1995a & b). Because of this barrier, ground water is within 20 feet of the ground surface north of the fault. There was no recorded liquefaction south of the fault, apparently because ground water is too deep.

As a result of the 1971 San Fernando earthquake, similar, but apparently less severe, ground cracking was mapped in the area around Van Gogh Street Elementary School (Locality 2, Plate 1.1) (Saul, 1974). Arcuate cracks on the school grounds showed down-to-the-east vertical offset. Although no sand boils or other clear indications of liquefaction were noted, Saul (1974) described subsidence features, and extensional and compressional ground cracks as being similar to those associated with liquefaction that occurred to the east (the Juvenile Hall lateral spread). Meehan (1974) stated "it is believed the ground displacement was due to liquefaction."

Artificial Fills

In the Oat Mountain Quadrangle the only areas of artificial fill large enough to show at the scale of the map are engineered fill for dams and freeways. Generally, the engineered fills are too thin to have an impact on liquefaction hazard and so were not investigated.

Areas with Sufficient Existing Geotechnical Data

The dense consistency and deep ground water encountered in boreholes into the very old alluvium exposed in the Northridge Hills (Qvoa1) indicates a low susceptibility to liquefaction. This geologic unit has not been included in a liquefaction zone in this area.

Older alluvial fans from the Santa Susana Mountains (Qof1) are generally moderately dense and are located in an area of deep ground water. Most of these areas are not included in a liquefaction zone. Three small canyon areas mapped as older alluvium extend north of the Mission Hills Fault into the Santa Susana Mountains. Because the fault forms a ground-water barrier to the east at Balboa Boulevard, these areas also probably have ground water at less than 40 feet below the surface. Because shallow ground water leads to moderate liquefaction susceptibility, these areas are included in liquefaction hazard zones.

Younger alluvial deposits (Qyf1, Qyf2, Qyt, Qw) of the alluvial fans have layers of loose to moderately dense sand or silty sand. Although many parts of these units are composed of silt and clay, sand layers occur in nearly all boreholes. Those sand layers generally have a factor of safety against liquefaction of less than one in the anticipated earthquake shaking. The low factors of safety indicate generally high liquefaction susceptibility for these units. Ground water is generally deeper than 40 feet north of the Northridge Hills, except in the Chatsworth basin. All younger alluvial fan deposits and stream channel deposits where ground water has been less than 40 feet from the surface have been included in the liquefaction zones.

All the alluvial units in the northern portion of the Oat Mountain Quadrangle were either shown to contain liquefiable sediments by the liquefaction analysis, or were judged to contain potentially liquefiable sediments by correlation with adjacent units or similar units, by relative age or mode of deposition, found in other portions of the study area. Geotechnical data were insufficient to fully analyze all the units in all parts of the study area.

Gavin Canyon and Newhall Creek valley contain only a few boreholes with SPT N values and liquefaction analyses. Boreholes with SPT N values and liquefaction analyses were not obtained for the small tributary canyons in this area and the unnamed valley east of Gavin Canyon. The depth to ground water in Gavin Canyon is less than 30 feet for most of the valley, whereas in the Newhall Creek valley and the unnamed valley east of Gavin Canyon ground water is interpreted to be at a depth of between 0 and 35 feet in most of the valley. All of Gavin Canyon and the parts of Newhall Creek valley and the unnamed valley east of Gavin Canyon where the shallowest ground water is less than 40 feet were included in the liquefaction zone, primarily based on the interpreted shallow ground water and on the overall liquefaction susceptibility of the underlying geologic units.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

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

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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 Oat Mountain 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 Oat Mountain 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 Oat Mountain 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 Oat Mountain 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 Oat Mountain Quadrangle covers an area of about 62 square miles in western Los Angeles County. Several suburban communities, all part of the City of Los Angeles, including Chatsworth, Northridge, and Granada Hills, lie near the southern edge of the quadrangle in the northern San Fernando Valley. North of the valley, the eastern half of the Santa Susana Mountains covers much of the remainder of the quadrangle, except for the northeastern corner, which contains a portion of the city of Santa Clarita. Canyons within the mountains trend southward toward the San Fernando Valley or northward toward the Santa Clara River drainage in the Newhall area. The center of the area is 26 miles northwest of downtown Los Angeles.

Oat Mountain, a broad ridge that trends northwesterly across the center of the quadrangle, dominates the terrain in the area. The ridgeline of Oat Mountain generally ranges between 3000 and 3500 feet in elevation. The highest elevation, 3747 feet, occurs at the western end of the Oat Mountain ridgeline. The south flank of Oat Mountain displays highly broken and irregular topography, in terrain that overlies the Santa Susana thrust fault and other faults located between the ridgetop and the north edge of the San Fernando Valley. The north flank of Oat Mountain and the succession of northwest trending ridges extending to the north have not been as extensively disrupted by faulting, so that the terrain is more regular. Ridges and drainage courses are narrow, with long steep slopes between ridgetop and stream bottoms.

Several large streams draining the south flank of Oat Mountain have eroded steep-walled canyons into the hills and alluvial fans along the northern edge of the San Fernando Valley. The Valley floor slopes gently toward the south, from an elevation of about 1100 feet at the base of the hills, to about 900 feet at the south edge of the quadrangle.

Interstate Highway 5 extends from San Fernando Pass, on the eastern edge of the quadrangle, northwesterly through the northeastern quarter of the quadrangle. Northeast of Highway 5, the hills become progressively lower and more subdued as they approach the nearly level terrain at the southern edge of the Santa Clarita Valley.

Residential and commercial development covers the floor of the San Fernando Valley, and is expanding into the hills along northern edge of the valley, between Limekiln and Bee canyons in the southeast quarter of the quadrangle. Residential development in the city of Santa Clarita is also rapidly expanding southward along stream bottoms and low hills in the northeast quarter of the quadrangle.

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 Oat Mountain 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 1947 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 Oat Mountain Quadrangle were identified (see Plate 2.1) on aerial photography flown in the winter and spring of 1994. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and reprocessed by Calgis, Inc (GeoSAR Consortium, 1995 and 1996). These terrain data were also smoothed prior to analysis.

A slope map was made from the corrected DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The original USGS DEM was then used to make a slope-aspect map. The slope map was used first in conjunction with the aspect map and geologic structural data to identify areas of potential adverse bedding conditions, and then again with the geologic strength map in the preparation of the earthquake-induced landslide hazard potential map.

GEOLOGY

Bedrock and Surficial Geology

For the Oat Mountain Quadrangle, a recently compiled geologic map (Yerkes and Campbell, 1993) was obtained from the U.S. Geological Survey (USGS) in digital form (Yerkes and Campbell, 1995). The geologic map was modified to reflect the most recent mapping in the area. 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.

The oldest geologic unit mapped in the Oat Mountain Quadrangle is the Upper Cretaceous Chatsworth Formation (USGS map symbol Kc), which forms spectacular tilted outcrops in the southwest quarter of the quadrangle near Santa Susana Pass. The Chatsworth Formation consists of massive, thick-bedded marine sandstone and conglomerate interbedded with thin-bedded siltstone and mudstone.

The Chatsworth Formation is overlain by the marine Paleocene Simi Conglomerate, which contains three mappable units (Tsc1, Tsc2, and Tsc3). Tsc1 is a well-indurated pebble-cobble conglomerate. Tsc2 is composed of shale, friable micaceous siltstone, and discontinuous sandstone and lenses of limestone. Tsc3 is locally well-cemented sandstone containing discontinuous conglomerate lenses and thin siltstone beds. Other lower Tertiary rock units exposed in the southwest quarter of the Oat Mountain Quadrangle include the marine upper Paleocene to lower Eocene Santa Susana Formation (Tss), which consists of micaceous, conchoidally fractured claystone with limestone concretions and minor fine- to medium-grained sandstone interbeds, and the lower to middle Eocene Llajas Formation, which is composed of poorly indurated, micaceous marine claystone, siltstone, sandstone, and nonmarine to shallow-marine basal conglomerate (Tl) and massive, ledge-forming, calcareous sandstone with abundant oyster and gastropod shells (Tlc).

Marine clastic and volcanic rocks of the middle Miocene Topanga Group crop out in the central part of the quadrangle near the Santa Susana Fault Zone. In the west-central map area, they consist of massive, friable sandstone with siltstone and conglomerate lenses (Tt) and deeply weathered, friable basaltic sills (Ttb). Topanga strata exposed in the eroded axis of the Aliso Anticline to the east have been differentiated into four units: soft, shaly siltstone (Tt1), well-indurated sandstone (Tt2), interbedded soft, fractured shale, siltstone, and mudstone (Tt3), and interbedded friable sandstone, siltstone, indurated sandstone, and conglomerate (Tt4).

Deep-marine clastic and biogenic rocks of the upper Miocene Modelo Formation are exposed along the axis of the Pico Anticline in the northern part of the area and form the broad ridgeline of Oat Mountain in the central part of the map. Modelo strata in the north consist of claystone, diatomaceous shale, cherty shale, and siltstone with minor sandstone interbeds (Tm). In the southwest quarter of the quadrangle, the Modelo Formation is subdivided into diatomaceous shale (Tmd) and interbedded siltstone and calcareous or siliceous shale (Tms) units. Modelo strata in the southeast quarter have been differentiated into five units: Tm1, shaly mudstone; Tm2, hard, porcelaneous shale; Tm3, well-indurated sandstone; Tm4, fractured shale with thin interbeds of sandstone; and Tmd, diatomaceous shale.

The Modelo Formation is overlain by and interfingers with the marine upper Miocene to lower Pliocene Towsley Formation, which is exposed in the northern third of the quadrangle on the flanks of the Pico Anticline and the Oat Mountain Syncline. Towsley strata consist of well-indurated sandstone (Tw), siltstone and mudstone (Tws), and well-cemented conglomerate and sandstone (Twc).

Plio-Pleistocene bedrock units in the Oat Mountain area include the Pico and Saugus formations. Pico strata crop out on the north flank of the Pico Anticline, in the axis of the Oat Mountain Syncline, and in isolated exposures in the southeast. The marine Pico Formation is divided into three units: undifferentiated sandstone and siltstone (Tp), soft, crumbly siltstone (Tps), and well-indurated sandstone and conglomerate (Tpc). Saugus strata are widely exposed in the northeastern part of the quadrangle and within and south of the Santa Susana Fault Zone in the central and southern part of the map. The Saugus Formation overlies and interfingers with the Pico Formation and is composed of interbedded shallow-marine to brackish water, moderately to well-indurated sandstone, siltstone, and minor conglomerate (Qsm), which grade laterally and vertically into nonmarine, loosely consolidated to moderately indurated sandstone, siltstone, and conglomerate (Qs, Qsu). The marine member of the Saugus Formation (Qsm) includes the brackish water Sunshine Ranch Member shown on previous maps.

Quaternary surficial deposits cover the floor and margins of the San Fernando Valley and the Santa Clarita Valley area and extend up into the canyons in the mountains bordering these valleys. In addition, there are numerous isolated areas of gently sloping terrain on the south flank of Oat Mountain where Quaternary surficial deposits have accumulated. Quaternary deposits in the area consist of upper Pleistocene nonmarine terrace and fan deposits, and Holocene and Pleistocene slope wash, landslide deposits, older alluvium and younger alluvium (Qto, Qt, Qyt, Qls, Qof1, Qvof2, Qyf1, Qyf2, Qvoa1, Qoa, Qay, Qay1, Qay2, Qc, Qsw, Qw, and Qal). Landslides are widespread in the central and northern portions of the Oat Mountain Quadrangle, occurring primarily on dipslopes in the finer grained Tertiary rock units and along the Santa Susana Fault Zone where the rocks have been repeatedly sheared and deformed. Modern man-made fills and cut-fills (af, acf), and areas of rockfall accumulations (rf) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Oat Mountain Quadrangle can be found in Section 1.

OAT MOUNTAIN QUADRANGLE
SHEAR STRENGTH GROUPINGS

	Formation Name	Number Tests	Mean/Median PHI	Group Mean/Median PHI (deg.)	Group Mean/Median Cohesion (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Tt	5	41.4/41	38.4/39.3	544/654	Tm1-fbc, Tm2-fbc, Tm3-fbc,Tm4-fbc	38
	Tsc	11	39.1/39			Tmd-fbc, Tms-fbc, Tsc1, Tsc2-fbc	
	Tm-fbc	7	39.0/39			Tsc3, Tt1-fbc, Tt2, Tt3-fbc, Tt4, Ttb	
	Kc	28	37.8/38			Tlc, Tl-fbc, Tss-fbc	
GROUP 2	Tpc/Tp-fbc	5	33.0/32	31.9/32.8	376/278		32
	Twc/Tw-fbc	2	34.0/34				
	Qs/Qsu	85	32.0/33				
	Qsm-fbc	13	31.9/33				
	Qvoa1/Qvof2	11	31.0/34				
	Qsw	12	30.9/31				
GROUP 3	Tps/Tp-abc	4	27.8/28	27.3/28.3	390/410	af, acf, rf, Qay, Qay1, Qay2, Qc, Qw	27
	Qsm-abc	13	27.7/28			Qt, Qao, Qto, Tws, Tw-abc, Tl-abc,	
	Qyf2/Qal	9	28.1/30			Tm-abc, Tm1-abc, Tm2-abc, Tm3-abc,	
	Qof1/Qoa	17	25.5/26			Tm4-abc, Tmd-abc, Tms-abc, Tt1-abc	
	Qyf1	7	29.0/30			Tt3-abc, Tss-abc, Tsc2-abc	
GROUP 4	Qls	6	20.3/25	20.3/25	490/465		8

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 Oat Mountain Quadrangle.

SHEAR STRENGTH GROUPS FOR OAT MOUNTAIN QUADRANGLE			
GROUP 1	GROUP 2	GROUP 3	GROUP 4
Tt	Qs	af	Qls
Tt1-fbc	Qsu	acf	
Tt2	Qsm-fbc	rf	
Tt3-fbc	Qvoa1	Qay	
Tt4	Qvof2	Qay1	
Ttb	Qsw	Qay2	
Tsc1	Tpc	Qc	
Tsc2-fbc	Tp-fbc	Qw	
Tsc3	Tw c	Qt	
Tm-fbc	Tw -fbc	Qyf2	
Tm1-fbc		Qal	
Tm2-fbc		Qyf1	
Tm3-fbc		Qyt	
Tm4-fbc		Qao	
Tmd-fbc		Qto	
Tms-fbc		Qof1	
Tlc		Qoa	
Tl-fbc		Qsm-abc	
Tss-fbc		Tps	

Table 2.2. Summary of the Shear Strength Groups for the Oat Mountain Quadrangle.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Oat Mountain Quadrangle was prepared (Irvine, unpublished) by using previous work done in the north half of the area (Treiman, 1987, Plate 10B) and 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: (NASA, 1994; USGS, 1969; USGS, 1952; and USGS, 1947; see Air Photos in References). Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Bishop, 1950; Dibblee, 1992; Evans and Miller, 1978; Harp and Jibson, 1995; Morton, 1976; Morton, 1975; Saul, 1979; Winterer and Durham, 1962; Yeats, 1987; and Yerkes, 1993). 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 Oat Mountain Quadrangle geologic map were obtained from a variety of sources (see Appendix A). Randy Jibson of the U.S. Geological Survey kindly provided a list of rock strength information he had compiled for the Oat Mountain Quadrangle directly from geotechnical consultant's in-house files. The locations of rock and soil samples taken for shear testing by consultants are shown on Plate 2.1.

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. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information. 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 and from Dibblee (1992) were 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.

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 Oat Mountain 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:	6.6
Modal Distance:	2.5 to 8.0 km
PGA:	0.68 to 01.2 g

The strong-motion record selected for the slope stability analysis in the Oat Mountain Quadrangle was the Channel 3 (north 35 degrees east 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 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 0.232 g. 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 Oat Mountain Quadrangle.

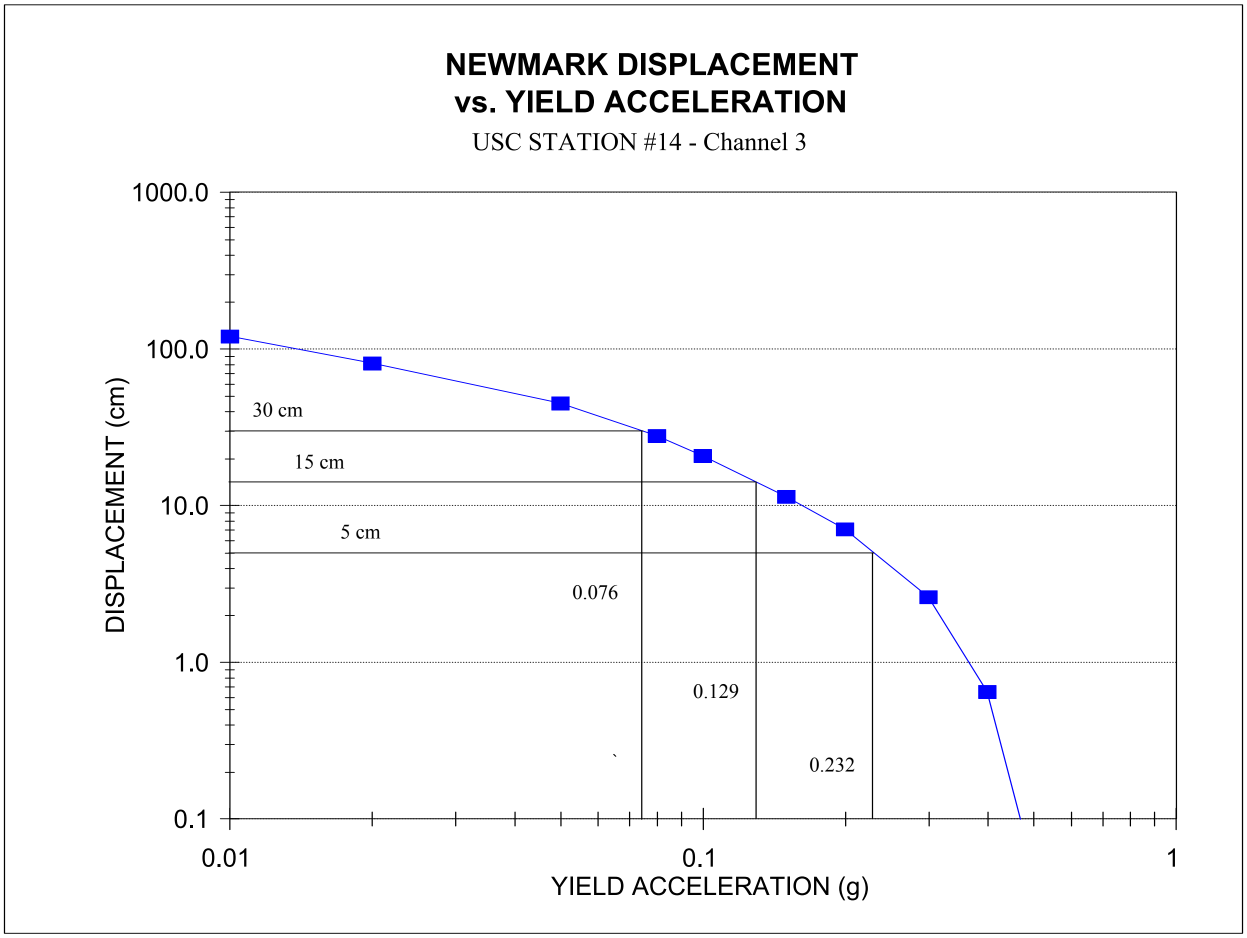

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the USC Station # 14 Strong-Motion Record From the 17 January 1994 Northridge, California Earthquake.

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.

OAT MOUNTAIN QUADRANGLE
HAZARD POTENTIAL MATRIX

Geologic Material Group	MEAN PHI	SLOPE CATEGORY I 0-7	II 8-29	III 30-38	IV 39-45	V 46-49	VI 50-53	VII 54-55	VIII 56-65	IX 66-70	X >70%
1	38	VL	VL	VL	VL	VL	VL	L	L	M	H
2	32	VL	VL	VL	L	L	M	M	H	H	H
3	27	VL	VL	L	M	H	H	H	H	H	H
4	8	M	H	H	H	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Oat Mountain 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.

Seismically induced landslides in the Oat Mountain Quadrangle were mapped by Morton (1975) following the February 9, 1971 San Fernando earthquake, and by Harp and Jibson (1995) following the January 17, 1994 Northridge earthquake. Both earthquakes triggered an abundance of landslides, predominantly rockfalls and soil falls. In addition to surficial failures, the Northridge earthquake caused several new bedrock landslides and reactivated portions of existing landslides in the vicinity of Oat Mountain and the Aliso Canyon Oil Field. Landslides attributed to the Northridge earthquake covered approximately 506 acres of land in the quadrangle (Harp and Jibson, 1995). The total area of Northridge-earthquake landslides within the quadrangle is less than 1.18% of the total area covered by the map. In the Oat Mountain Quadrangle, 90% of the landslides triggered by the Northridge earthquake lie within the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory. The difference may reflect run-out of soil falls or dust deposits inferred to be landslide features.

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 4 is included for all slope gradient categories. (Note: Geologic Strength Group 4 includes all mappable landslides with a definite or probable confidence rating).

2. Geologic Strength Group 3 is included for all slopes steeper than 29 percent.

3. Geologic Strength Group 2 is included for all slopes steeper than 38 percent.

4. Geologic Strength Group 1is included for all slopes steeper than 53 percent.

This results in 39 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Oat Mountain Quadrangle.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
U.S. Geological Survey rock strength data compiled by Randy Jibson from geotechnical investigations performed by consulting firms in the Oat Mountain Quadrangle	**91**
City of Los Angeles, Department of Building and Safety	**86**
Los Angeles County Department of Public Works Material Engineering Division files	**58**
Total Number of Shear Tests	**235**

SECTION 3
GROUND SHAKING EVALUATION REPORT

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

By

Mark D. Petersen*, Chris H. Cramer*, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

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.consrv.ca.gov/dmg/shezp/

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.

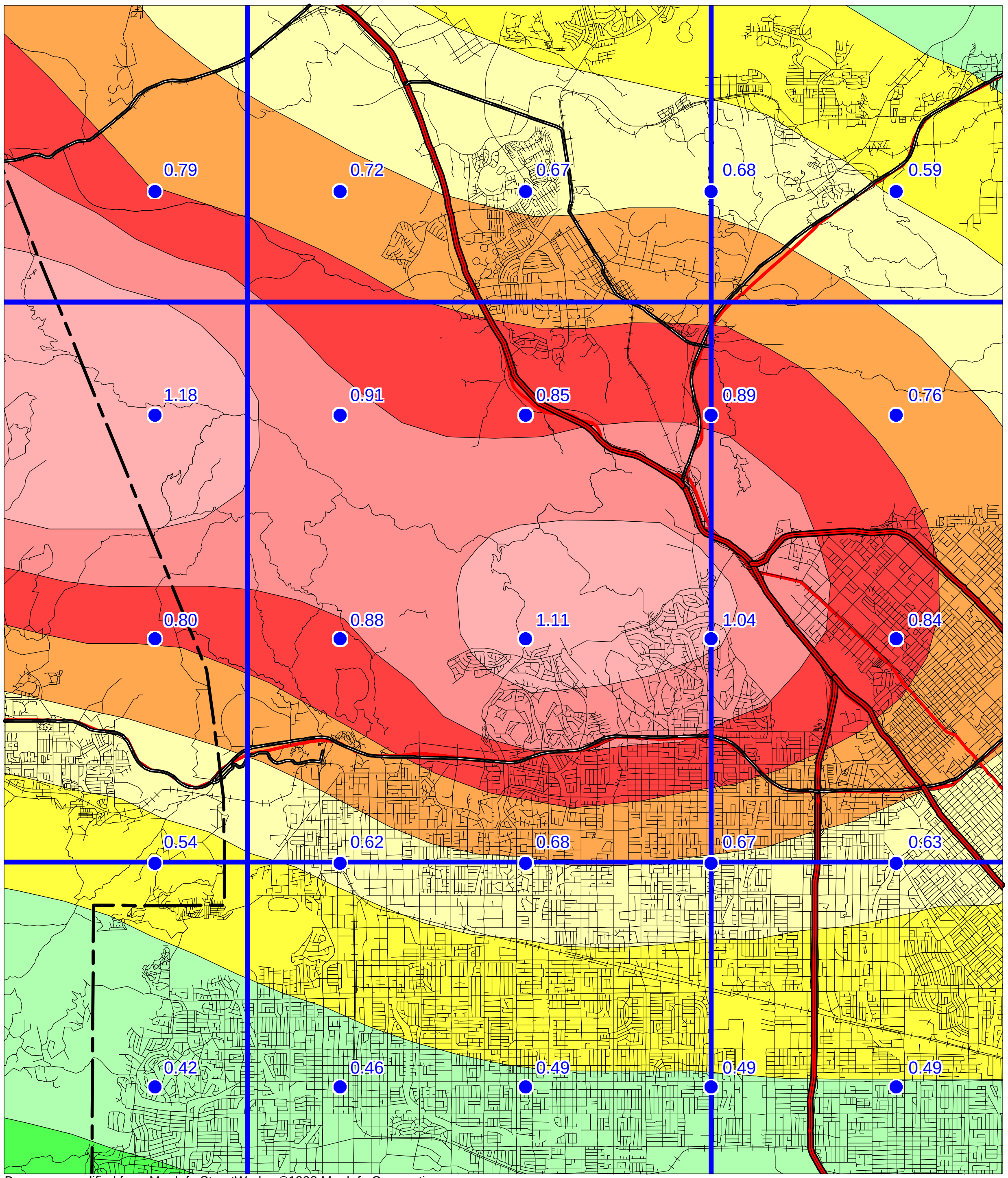
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. 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

OAT MOUNTAIN 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

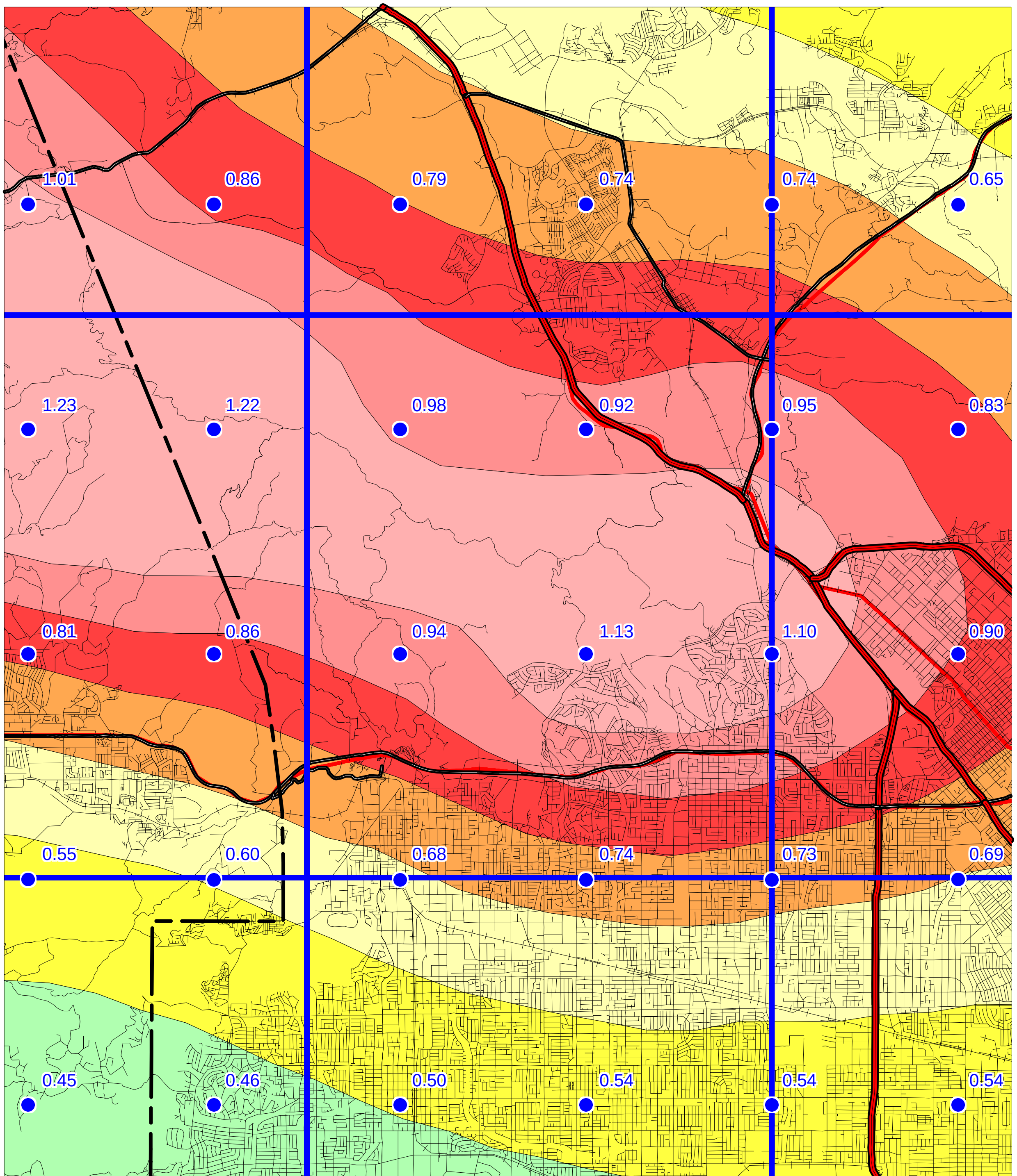
Figure 3.1

OAT MOUNTAIN 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



0 2.5 5
Kilometers

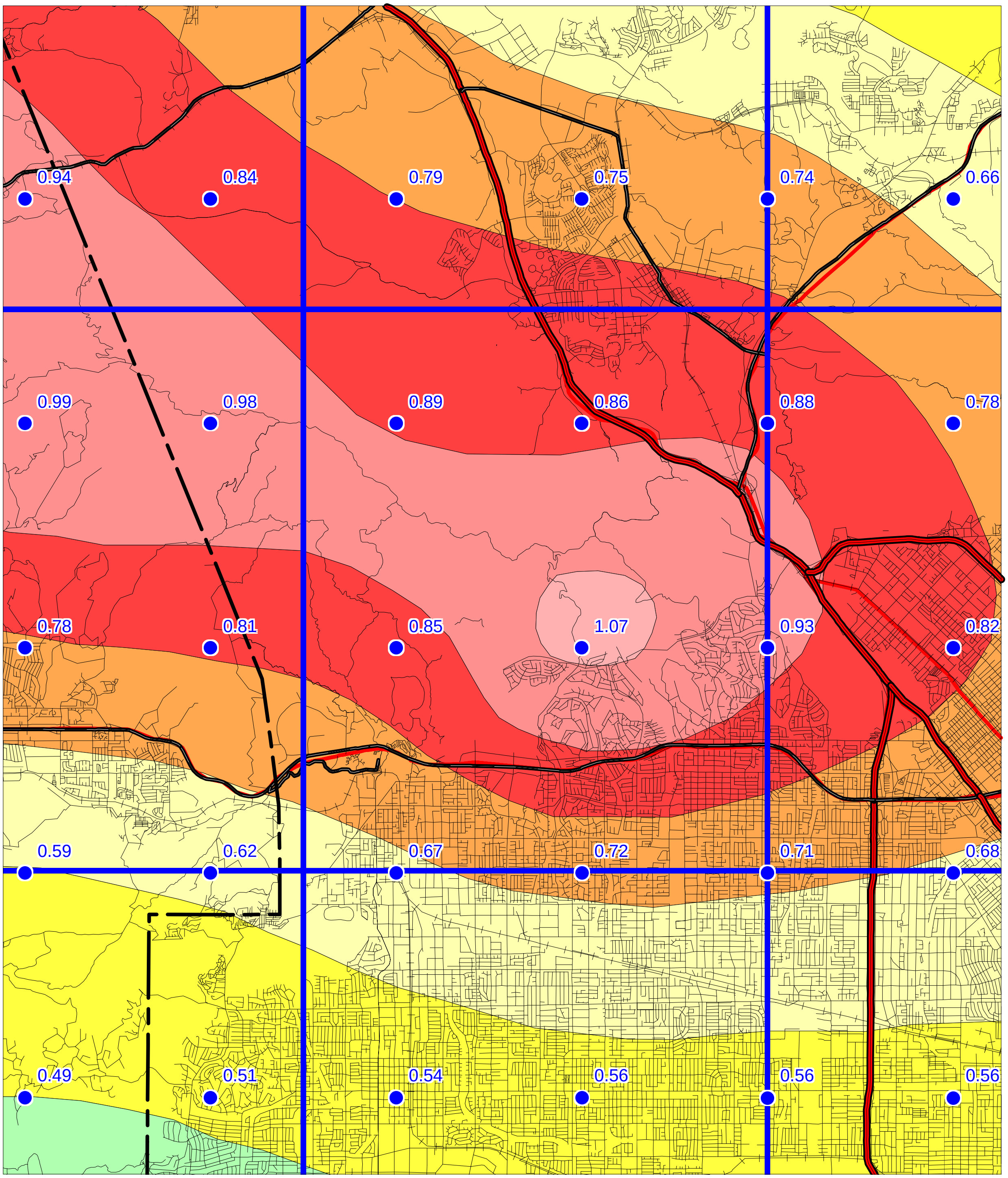
Department of Conservation
Division of Mines and Geology

Figure 3.2

OAT MOUNTAIN 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.

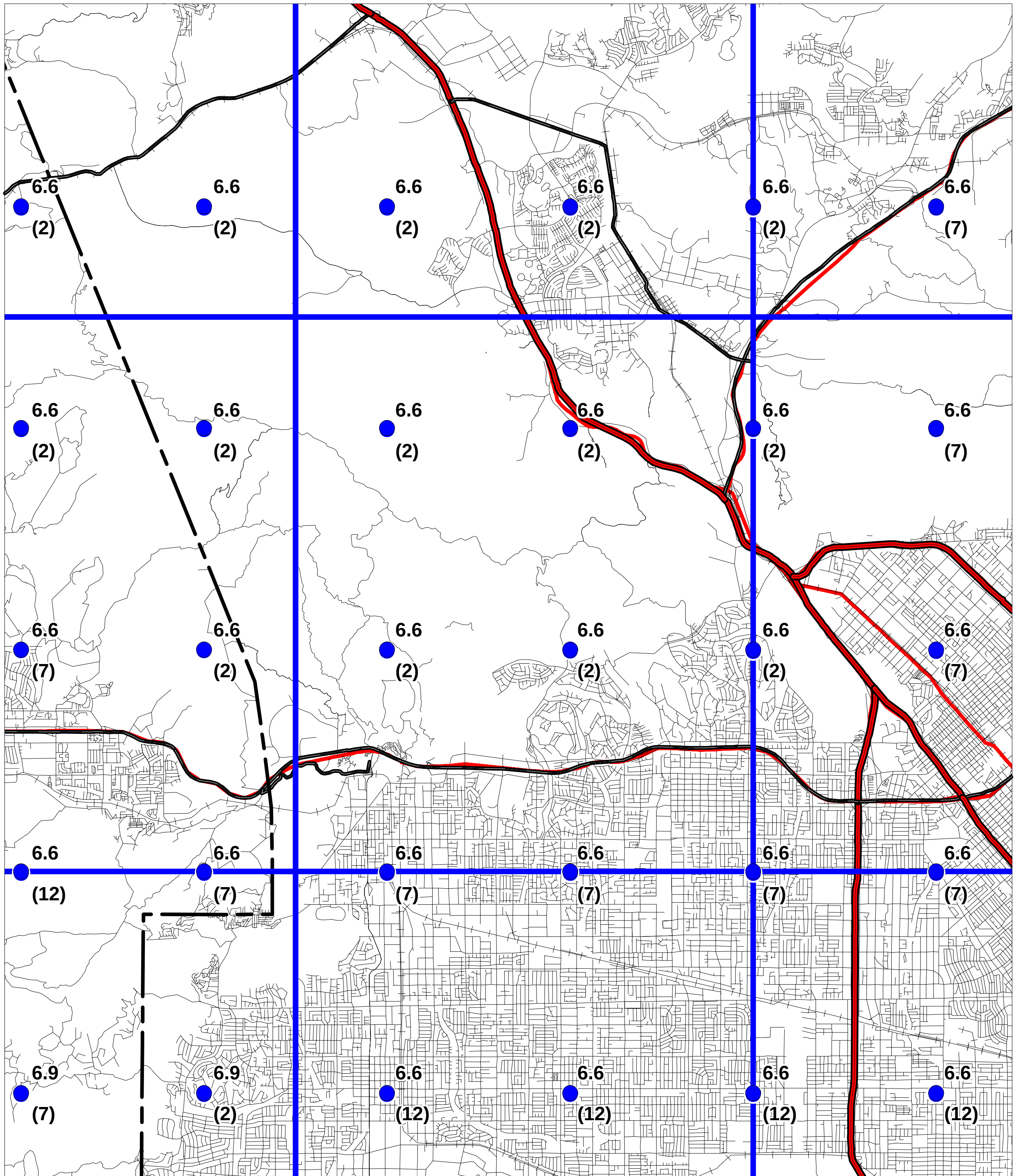
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

OAT MOUNTAIN 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

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



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

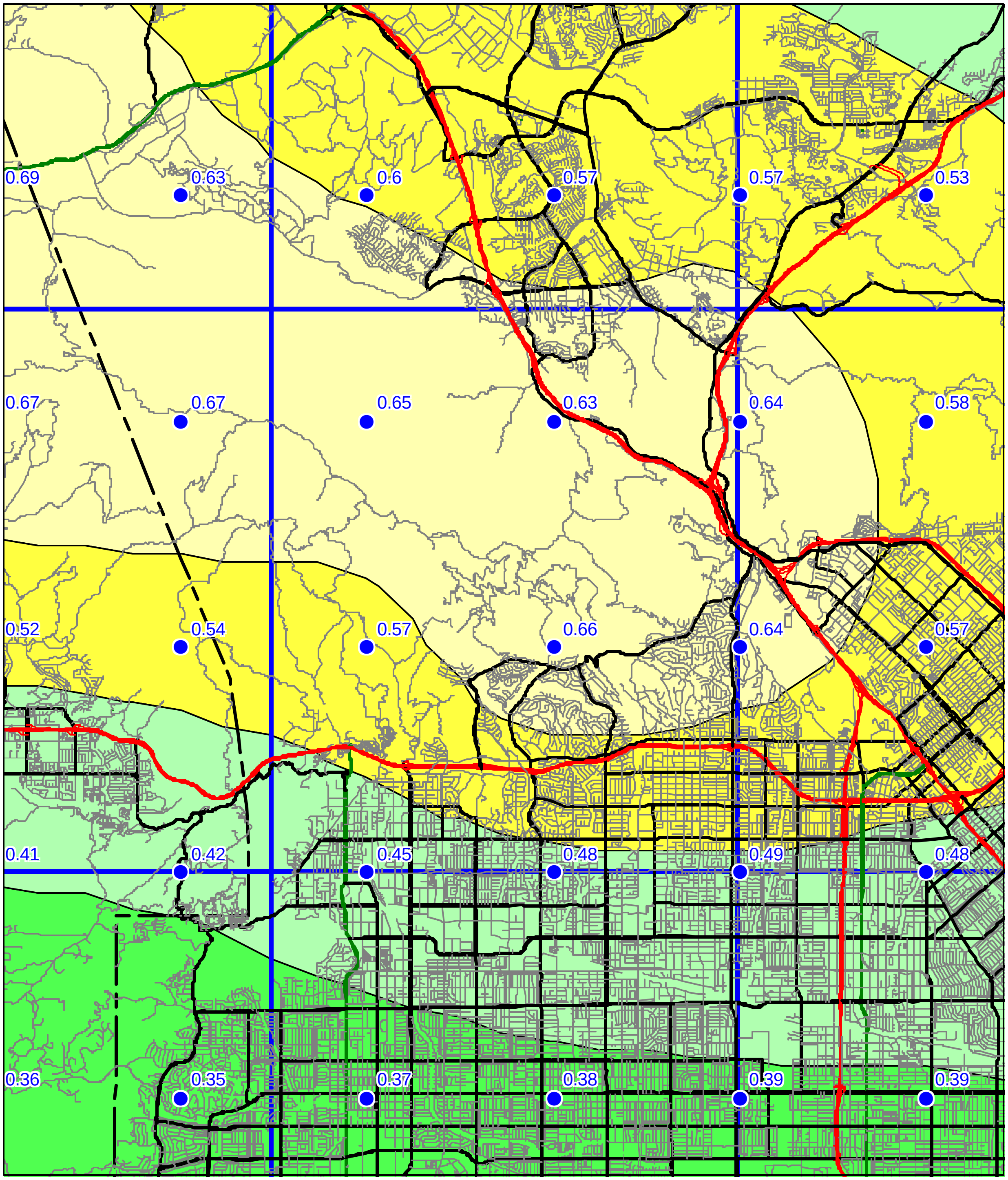
Figure 3.4

OAT MOUNTAIN 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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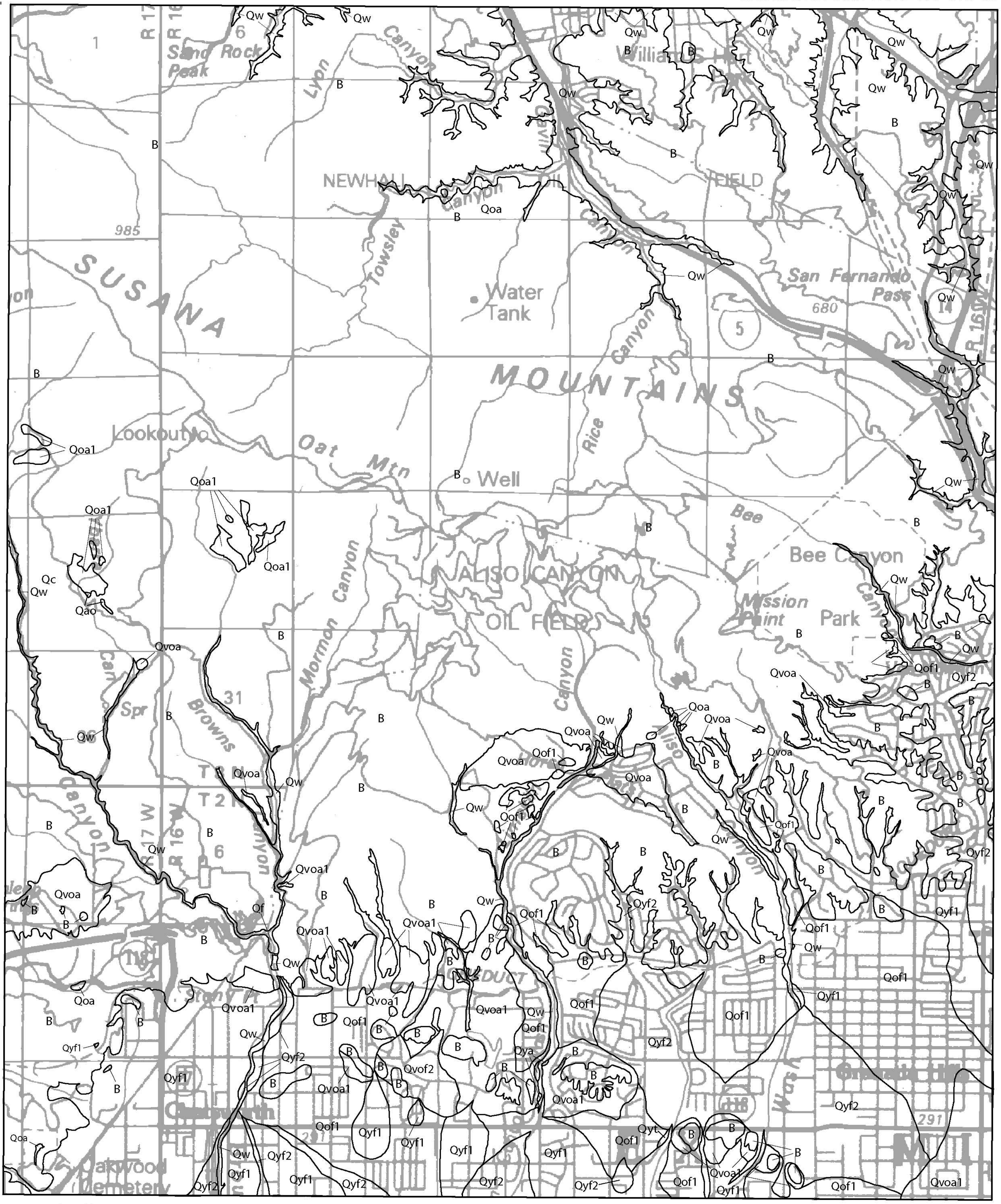
118°37'30"
34°22'30"



34°15'
118°30'

Base map enlarged from U.S.G.S. 30 x 60-minute series

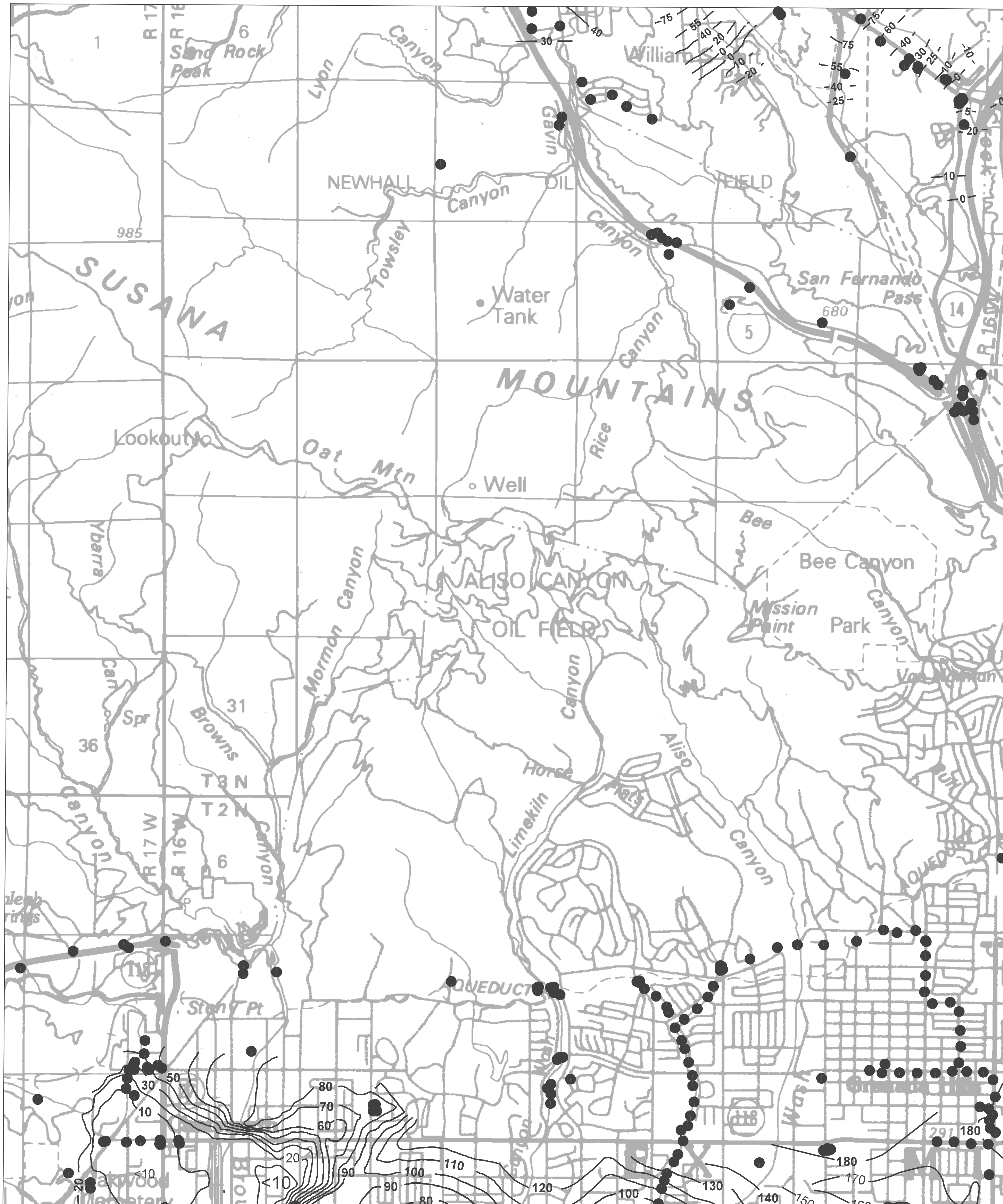
B = Pre-Quaternary bedrock
See "Bedrock and Surficial Geology" in Section 1 of the report for descriptions of units.

ONE MILE
SCALE

Plate 1.1 Quaternary Geologic Map of the Oat Mountain 7.5-Minute Quadrangle, California

118° 37'30"

34° 22'30"



34° 15'

Base map enlarged from U.S.G.S. 30 x 60–minute series

118° 30'

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Oat Mountain 7.5–minute Quadrangle, California.

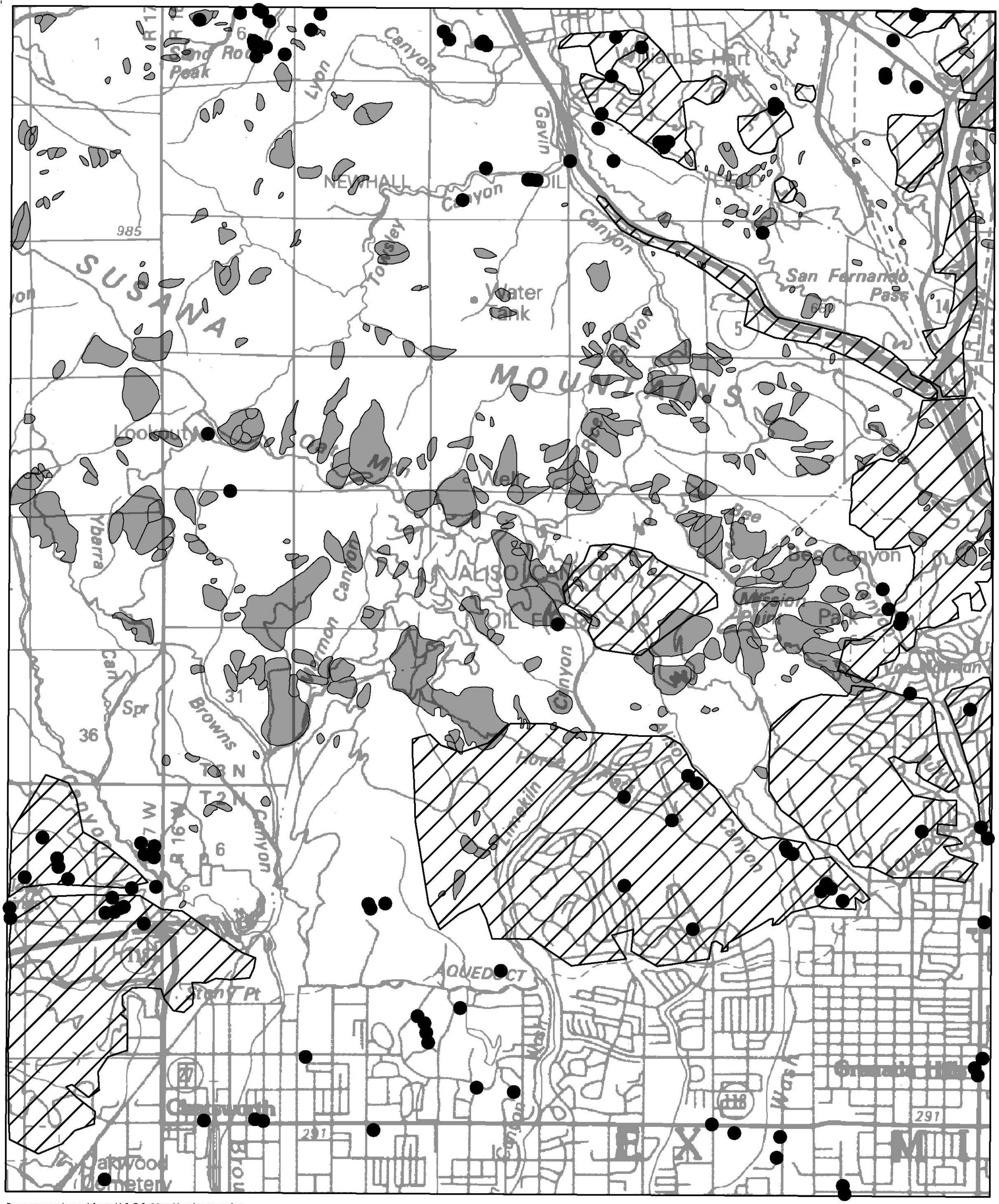
● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE

118°37'30"
34°22'30"



34°15'
118°30'

Base map enlarged from U.S.G.S. 30 x 60-minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, Oat Mountain 7.5-Minute Quadrangle, California.

● shear test sample location

landslide

Areas of signifacant grading

ONE MILE

SCALE