SEISMIC HAZARD ZONE REPORT 084

SEISMIC HAZARD ZONE REPORT FOR THE BRIONES VALLEY 7.5-MINUTE QUADRANGLE, ALAMEDA COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Alameda County portion of the Briones Valley 7.5-Minute Quadrangle. The map displays the boundaries of zones of required investigation for earthquake-induced landslides over an area of approximately one square mile at a scale of 1 inch = 2,000 feet. No zones of required investigation for liquefaction were mapped in the Alameda County portion of the Briones Valley Quadrangle.

An Official Seismic Hazard Zone map covering the City of Oakland, which includes most of the Alameda County portion of the Briones Valley Quadrangle, was prepared in 1999. This new map discussed in this report includes earthquake-induced landslide zones of required investigation for the part of the City of Berkeley that also extends into the quadrangle. Alameda County land within the Briones Valley Quadrangle is within the deeply dissected Berkeley Hills. Within the City of Berkeley, residential development occupies the northern portion of the mapped area and the University of California lies at the south end. The only significant development within the City of Oakland is a portion of the Lawrence Berkeley Laboratory.

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, 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 percent probability of exceedance in 50 years.

In the Briones Valley Quadrangle the combination of dissected terrain and weak rocks has produced abundant landslides. These conditions contribute to an earthquake-induced landslide zone that covers about 55 percent of the Alameda County land area in the Briones Valley 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 California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

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

BPS Reprographic Services
149 Second 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 CGS 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) [now called California Geological Survey (CGS)] 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 adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

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 CGS 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 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 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Briones Valley 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Briones Valley 7.5-Minute Quadrangle, Alameda County, California

California Department of Conservation
California Geological Survey

NO LIQUEFACTION HAZARDS ZONED

Within the Alameda County portion of the Briones Valley 7.5-Minute Quadrangle, no areas have been designated as "zones of required investigation for liquefaction." At the 1:24,000 scale of mapping used in producing Seismic Hazard Zone Maps, no areas of saturated, young granular materials were identified. The Alameda County part of the Briones Valley Quadrangle is hilly and is underlain by bedrock, not young, unconsolidated sediment.

SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Briones Valley 7.5-Minute Quadrangle, Alameda County, California

By
Timothy P. McCrink, Mark O. Wiegers, Rick I. Wilson, Wayne D. Haydon, and Jack R. McMillan

California Department of Conservation
California 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) [now called California Geological Survey (CGS)] 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 CGS 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). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Alameda County portion of the Briones Valley 7.5-Minute Quadrangle. The area consists of about one square mile in the southwestern corner of the quadrangle where small parts of the cities of Berkeley and Oakland occur. The remainder of the Briones Valley Quadrangle is in Contra Costa County. Seismic hazard zone mapping in Contra Costa County is planned.

There is no Section 1 because there are no liquefaction hazard zones in the Alameda County portion of the quadrangle. Section 3 (addressing earthquake shaking) completes the report, which 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 the California Geological Survey's Internet page: http://www.consrv.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 in the cities of Berkeley and Oakland in the Briones Valley 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 CGS 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 CGS pilot study (McCrink and Real, 1996; McCrink, 2001) 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.

This map covers only the portion of the Briones Valley Quadrangle that lies within Alameda County. Official Seismic Hazard Zone maps covering the City of Oakland, which includes most of the Alameda County portion of the Briones Valley Quadrangle, were prepared in 1999 and released in March 2000 (DOC, 1999). With release of this new map and report, the remaining areas within Alameda County on the Briones Valley Quadrangle have been mapped for seismic hazards. The most significant change to the Briones Valley Quadrangle Zone Map is the preparation of earthquake-induced landslide zones of required investigation for the City of Berkeley at the southwestern edge of the quadrangle. The previously identified landslide zones of required investigation within the City of Oakland have been slightly modified to include two recently identified landslides on the Oakland-Berkeley boundary.

The remainder of this report describes in detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Briones Valley 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

Alameda County land within the Briones Valley Quadrangle is hilly and deeply dissected, primarily in the upper reaches of the Strawberry Creek watershed. Slopes over much of the area are 2:1 (horizontal:vertical) or steeper and are covered by a variety of vegetation, including conifers, eucalyptus, grasses and shrubs. The highest point in the Alameda County portion of the Briones Valley Quadrangle is little over 1,740 feet above sea level on a ridgetop at the crest of the Berkeley Hills.

Within the City of Berkeley, residential development occupies the northern portion of the mapped area and the University of California lies at the south end. The only significant development within the City of Oakland is a portion of the Lawrence Berkeley Laboratory.

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 in the form of a digital topographic map. Within the City of Berkeley, digital topography in the form of a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1958 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Digital topography within the City of Oakland relied on a set of digital terrain files obtained from the City of Oakland. These files contained digitized contours, breaklines, and spot elevations that were collected from stereo-pair aerial photography flown in 1994. The files were first translated into a format usable by CGS and then converted to a triangular-irregular-network (TIN) computer model. Finally, they were converted into a regularly spaced digital elevation model (DEM) with a 10-meter horizontal resolution and a vertical accuracy estimated to be on the order of 1 to 2 meters.

A slope map was made from the corrected DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). 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

The primary source of bedrock geology used in this slope stability evaluation is the geologic map and map database of the Oakland metropolitan area by Graymer (2000). This digital geologic database was compiled at a resolution of 1:24,000 from previously published reports and from new mapping and field checking by Graymer (2000). A geologic map by Dibblee (1980) also was reviewed.

The geology of the Berkeley Hills is characterized by two highly deformed Mesozoic basement assemblages that are unconformably overlain by Tertiary sedimentary and volcanic rocks and unconsolidated Quaternary deposits. These two Mesozoic basement complexes are the Great Valley Complex and the Franciscan Complex (Graymer, 2000). Only the Great Valley Complex extends into the Alameda County part of the Briones Valley Quadrangle. The Franciscan Complex lies southwest of the map area.

The Great Valley Complex includes the Coast Range Ophiolite, which is composed of serpentinite, gabbro, diabase, basalt and keratophyre (altered silicic volcanic rock), and the Great Valley Sequence, which is composed of sandstone, conglomerate and shale of Jurassic and Cretaceous age (Graymer, 2000). Coast Range Ophiolite rocks are not exposed in the map area. One unit of the Great Valley Sequence, undivided Cretaceous sandstone, siltstone, shale and minor conglomerate (Ku), is exposed in the southwesternmost corner of the quadrangle.

The Great Valley Complex is unconformably overlain by Miocene marine and nonmarine sedimentary volcanic rocks (Graymer, 2000). The oldest Miocene unit is the late to middle Miocene Claremont Chert (Tcc). This unit consists of laminated to bedded chert with minor shale and sandstone. The Claremont Chert is overlain by the Orinda Formation of late Miocene age (Tor). This unit consists of pebble to boulder conglomerate, conglomeratic sandstone, silstone and mudstone. The Orinda Formation is overlain by the Moraga Formation of late Miocene age. The Moraga Formation consists of basalt and andesite flows with minor rhyolite tuff. The Moraga Formation is overlain

by the late Miocene Siesta Formation (Tst). The Siesta Formation consists of nonmarine siltstone, claystone, sandstone and minor limestone.

Structural Geology

The bedrock structure in the East Bay hills results from a complex deformational history. Deformation included Mesozoic and early Tertiary subduction and accretion, early to mid-Tertiary uplift and attenuation faulting and, finally, a period of strike-slip and reverse faulting that began in the late Miocene and remains active today.

The Hayward Fault, one of the major active faults in the region, passes very close (within several hundred feet) to the southwest corner of the Briones Valley Quadrangle. The Hayward Fault is a major right-lateral, strike-slip fault of the San Andreas Fault system.

Bedrock units in the study area have been strongly tilted and folded and generally dip moderately to steeply to the northeast and southwest. The study area is on the southwestern limb of the Siesta Valley Syncline, a large prominent northwest-trending syncline with an axis about one-half mile northeast of the study area.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in Berkeley and Oakland was prepared by field reconnaissance, analysis of stereo-paired aerial photographs (see Air Photos in References) and review of previously published landslide mapping (Nilsen, 1975). Landslides were mapped 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 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.

In general, landslides are abundant in the hillside areas of Oakland and Berkeley. Landslide movement has periodically damaged homes and other improvements in both cities. Landslides range from large, deep-seated features that may be several thousand feet in diameter to small shallow debris and earth slides that may be confined to a single lot or a small section of roadway.

Several relatively large earthflows and debris slides are present in the Alameda County portion of the Briones Valley Quadrangle. Several of these have required corrective work on lands of the Lawrence Berkeley Laboratory. Others are on undeveloped slopes. There are many other landslides in portions of the Briones Valley Quadrangle that lie outside of Alameda County, which have not been mapped for this study.

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 shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Briones Valley Quadrangle geologic map were obtained from cities of Berkeley, Oakland and Piedmont, Alameda County, the University of California at Berkeley, Lawrence Berkeley Laboratory, Berlogar Geotechnical Consultants, Harza Engineering Company, and the CGS Environmental Review Project (see Appendix A). The locations of rock and soil samples taken for shear testing within the Briones Valley Quadrangle are shown on Plate 2.1. Shear tests from the adjoining Richmond, Oakland West and Oakland East quadrangles were used to augment data for several geologic formations for which little or no shear test information was available within the Briones Valley Quadrangle.

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. This study relied heavily upon the data and analyses previously conducted for the zone map prepared for the City of Oakland (DMG, 1999). This previous work incorporated evaluations of shear strength parameters for geologic units that do not occur within the Briones Valley Quadrangle. Nevertheless, because these other geologic units significantly controlled the development of the shear strength groups for formations that do occur in the Briones Valley Quadrangle, they were incorporated into the slope stability analyses and are shown on Table 2.1. Table 2.2 lists by strength group only those geologic units found in the Briones Valley Quadrangle. An average (mean or median) phi value for each geologic strength group was used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

A number of geologic units were subdivided further, as described below.

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, 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 category was less than or equal to the slope gradient category, but greater than 25 percent (4:1 slope), the area was marked as a potential adverse bedding area.

Most formations within the Alameda County portion of the Briones Valley Quadrangle were found to have the stratigraphic and material strength characteristics conducive to adverse bedding conditions. However, the analysis of the geologic structure and terrain described above indicates that the areas of adverse bedding conditions are likely to exist in the Alameda County portion of the Briones Valley Quadrangle. Regardless, the geologic material strength groups are presented in terms of favorable and adverse conditions on Table 2.1 because these strength groups were developed in conjunction with, and used for adverse bedding conditions in the adjacent Richmond and Oakland East quadrangles.

Existing Landslides

As discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

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.

Within the Briones Valley Quadrangle only one shear test of landslide slip surface materials was available. Ten additional direct shear tests of slip surface materials were obtained from the adjacent Oakland East quadrangle, and the results are summarized in Table 2.1.

BRIONES VALLEY QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Tsm(fbc)*	5	40/41	41/41	535/500		41
	Tush(fbc)*	2	40/40			Tbr(fbc)	
	KJfs(fbc)*	3	43/50				
GROUP 2	Tcc(fbc)	4	33/30	33/33	628/450	Tbp(fbc)	33
	Tes(fbc)*	1	31/31			Tst(fbc)*	
	Tmb(fbc)	2	35/37				
	Tor(fbc)	37	32/31				
	Kfn(fbc)*	11	33/33				
	Kjm(fbc)*	28	33/33				
	Ko(fbc)*	14	34/35				
	Kr(fbc)*	3	34/33				
	Ksc(fbc)*	1	32/32				
	Ku(fbc)	15	32/31				
	KJf(fbc)*	4	33/32				
	KJfm(fbc)*	11	35/35				
	Jgb*	17	31/32				
	Jsv*	28	31/33				
GROUP 3	af*	40	28/28	28/27	491/315		28
	Qhf*	32	27/26				
	Qhms*	9	27/28				
	Tcc(abc)	3	29/30				
	Jb*	3	28/27				
GROUP 4	Qhl	2	23/23	23/22	656/315		23
	Qmt*	3	21/21			Tbr(abc)	
	Qpf*	42	24/24			Tbp(abc)	
	Qof*	11	24/23			Tst(abc)	
	Ta(abc)*	2	25/25				
	Tes(abc)*	2	25/25				
	Tmb(abc)	4	24/23				
	Tor(abc)	28	21/21				
	Tsm(abc)*	12	24/23				
	Kfn(abc)+	10	21/20				
	Kjm(abc)*	20	21/23				
	Ko(abc)*	13	22/23				
	Kr(abc)*	10	21/22				
	Ksc(abc)*	4	24/21				
	Ku(abc)	51	22/21				
	KJf(abc)*	1	25/25				
	KJfm(abc)*	21	23/22				
	KJfs(abc)*	5	21/18				
	KJk(abc)*	7	24/26				
	Jsp*	4	24/25				
GROUP 5	Qls	11	12/10	12/10	725/420		12

abc = adverse bedding condition, fine-grained material strength

fbc = favorable bedding condition, coarse-grained material strength

* = These formations do not occur in the mapped portion of the Briones Valley Quadrangle but were used in the determination of the material strength groups.

Bedrock formation abbreviations for strength groups from Graymer (2000); Quaternary unit abbreviations from Knudsen and others, (2000)

Table 2.1. Summary of the Shear Strength Statistics for the Briones Valley Quadrangle.

SHEAR STRENGTH GROUPS FOR THE BRIONES VALLEY 7.5-MINUTE QUADRANGLE				
GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Tbr (fbc)	Tmb(fbc) Tor(fbc) Tst(fbc) Tbp(fbc) Tcc(fbc) Ku(fbc)	Tcc(abc)	Tmb(abc) Tor(abc) Tst(abc) Tbp(abc) Tbr (abc) Ku(abc)	Qls

Table 2.2. Summary of Shear Strength Groups for the Geologic Formations that Occur within the Mapped Portion of the Briones Valley Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity."

Because the active Hayward Fault traverses less than one half kilometer southwest of the Briones Valley Quadrangle, the selection of a strong motion record was based on the desire to simulate a large earthquake on the Hayward Fault. The Hayward Fault is a right-lateral strike-slip fault with a total length of approximately 86 km and an estimated maximum moment magnitude of 7.1 (Petersen and others, 1996). The Berkeley Hills, which would be susceptible to earthquake-induced landsliding, range from zero to about 5 km from the seismic source. Strong-motion records considered in the selection include: the CGS Strong Motion Instrumentation Program (SMIP) Corralitos record from the 1989 Loma Prieta earthquake; the Southern California Edison (SCE) Lucerne record from the 1992 Landers earthquake; and the Japan Meteorological Agency (JMA) Kobe City record from the 1995 Hyogoken-Nambu (Kobe) earthquake. The significant parameters for each of these earthquakes are listed below:

Strong-Motion Record	Moment Magnitude	Source to Site Distance (km)	PGA (g)
SMIP Corralitos	6.9	5.1	0.64
SCE Lucerne	7.3	1.1	0.80
JMA Kobe	6.9	0.6	0.82

The Corralitos record was eliminated because the fault motion was oblique, rather than purely strike-slip, and because of the relatively short rupture length. The Kobe record was eliminated because of uncertainties regarding the effects of topographic and basin-edge amplification at the recording site. Despite the slightly higher than expected magnitude, the Lucerne record from the 1992 Landers earthquake was used because it has many tectonic similarities to an earthquake on the Hayward Fault.

The selected strong-motion record was not scaled or otherwise modified prior to 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 CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.14, 0.18 and 0.24g. 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 Briones Valley Quadrangle.

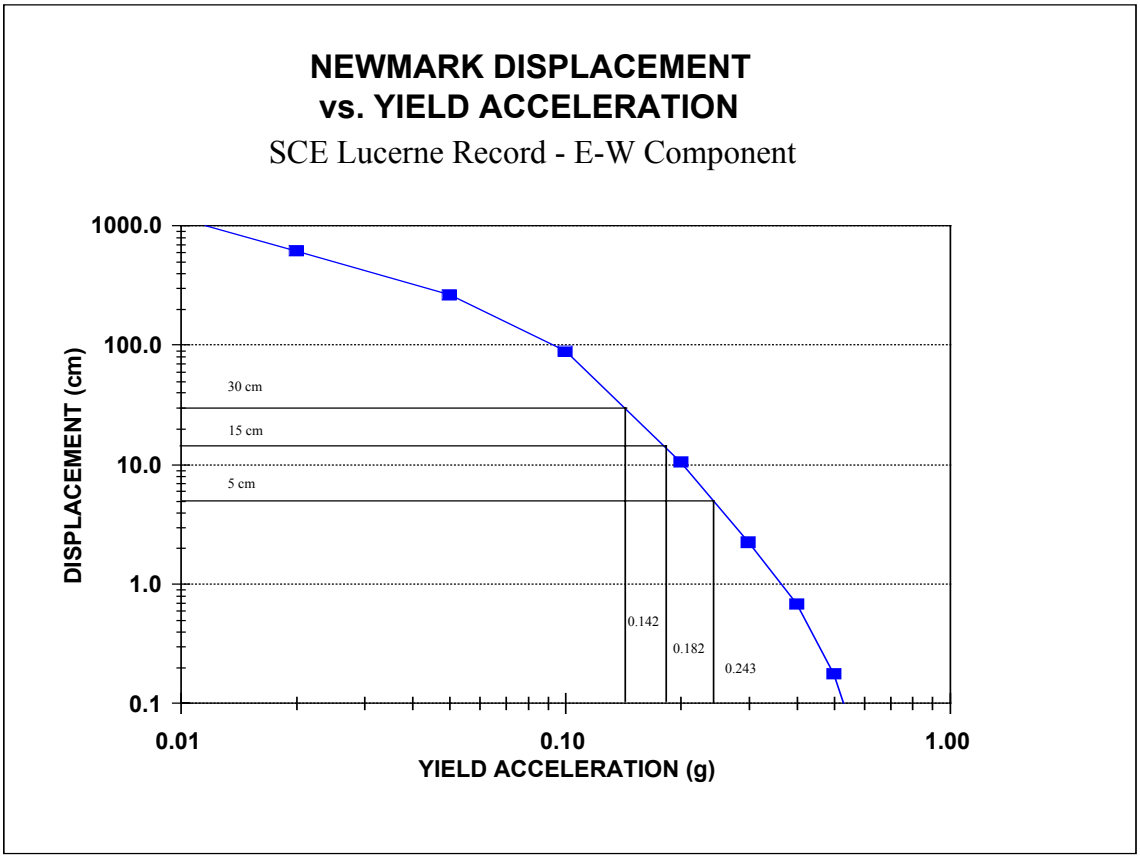

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Southern California Edison Lucerne Record.

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 0.14 g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned

2. If the calculated yield acceleration fell between 0.14 g and 0.18 g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned

3. If the calculated yield acceleration fell between 0.18 g and 0.24 g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned

4. If the calculated yield acceleration was greater than 0.24 g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned

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.

BRIONES VALLEY QUADRANGLE HAZARD POTENTIAL MATRIX				
Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (41)	0 to 59%	60 to 65%	66 to 69%	70%+
2 (33)	0 to 38%	39 to 44%	45 to 49%	50%+
3 (28)	0 to 27%	28 to 33%	34 to 37%	38%+
4 (23)	0 to 18%	19 to 23%	24 to 27%	28%+
5 (12)	0%	0%	0 to 5%	6%+

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Briones Valley Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

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.**

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

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

1. Geologic Strength Group 5, consisting of all definite and probable landslide areas, is always included in the earthquake-induced landslide zone regardless of slope.

2. Geologic Strength Group 4 is included for all slopes steeper than 18 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 27 percent.

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

5. Geologic Strength Group 1 is included for all slopes steeper than 59 percent.

This results in approximately 55 percent of the Alameda County land area in the Briones Valley Quadrangle lying within the earthquake-induced landslide hazard zone.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. At the City of Berkeley Jay Wilson and Glenn Carloss greatly facilitated the collection of shear strength information. Alan Kropp of Alan Kropp Associates generously allowed access to his archive of consultant report files and collection of historic landslide information. Paul Lai at Berlogar Geotechnical Consultants allowed access to his firm's geotechnical reports. Data collection for the earlier Oakland zone map, which this study used extensively, was facilitated by Joan Curtis and Mario Millan from the City of Oakland; Vern Phillips and Chester Nakahora from the City of Piedmont; Peter Dilks and Gary Moore from Alameda County; Herb Lotter from the City of Berkeley; Jeff Gee, Ron Gaul, and Nico Sanchez from the University of California at Berkeley; Fred Angliss from the Lawrence Berkeley Laboratory; and, Mark Caruso and Ken Ferrone from Harza Engineering Company. The selection of a representative strong-motion seismic record was greatly facilitated by discussions with Charles Real, Mark Petersen, Chris Cramer and Paul Summerville, and the displacement calculations for the considered records were carried out by Jacob Summerhayes. At CGS, Terilee McGuire, Lee Wallinder and Bob Moscovitz provided GIS support. Anne Rosinski and Kevin Clahan assisted in the shear test data collection. Barbara Wanish and Ross Martin prepared the final landslide hazard zone maps and the graphic displays for this report.

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AIR PHOTOS

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WAC Corporation, Inc, dated 4/99, Flight WAC-C-99CA, Photos 3-230 through 3-238, 11-145 through 11-148, 3-208 through 3-215, scale 1:24,000

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Oakland	243
Alameda County	101
Lawrence Berkeley Laboratory	41
University of California at Berkeley	36
Berlogar Geotechnical Consultants	31
City of Berkeley	20
Harza Engineering Company	12
City of Piedmont	8
CGS Environmental Review Project	3
TOTAL	495

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Briones Valley 7.5-Minute Quadrangle, Alameda County, California

By

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

California Department of Conservation
California Geological Survey
***Formerly with CGS, 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) [now called California Geological Survey (CGS)] 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). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

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 (DOC, 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 the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], 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 percent 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.

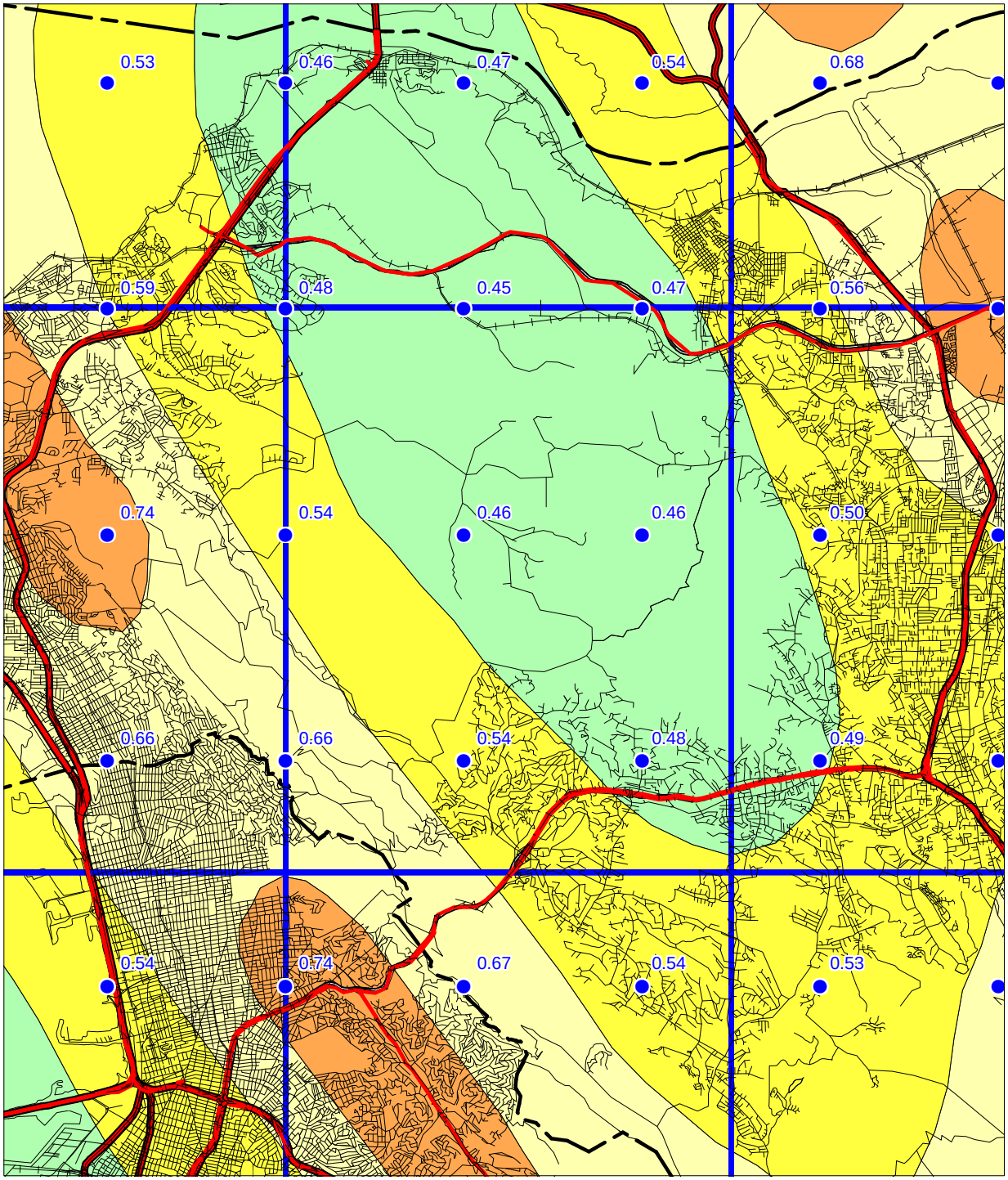
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

BRIONES VALLEY 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 1.5 3
Miles

Department of Conservation
California Geological Survey

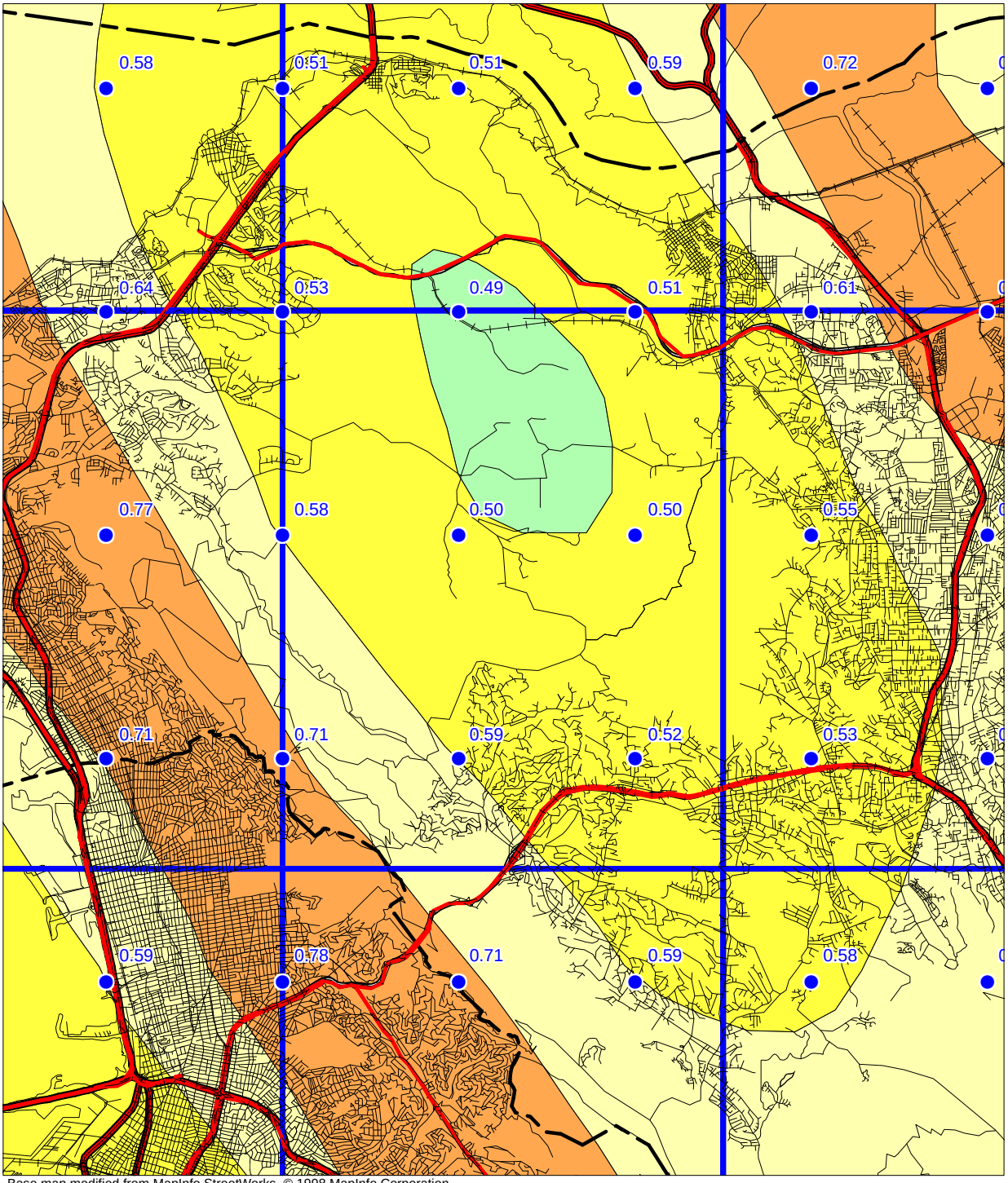
Figure 3.1

BRIONES VALLEY 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3
Miles

Department of Conservation
California Geological Survey

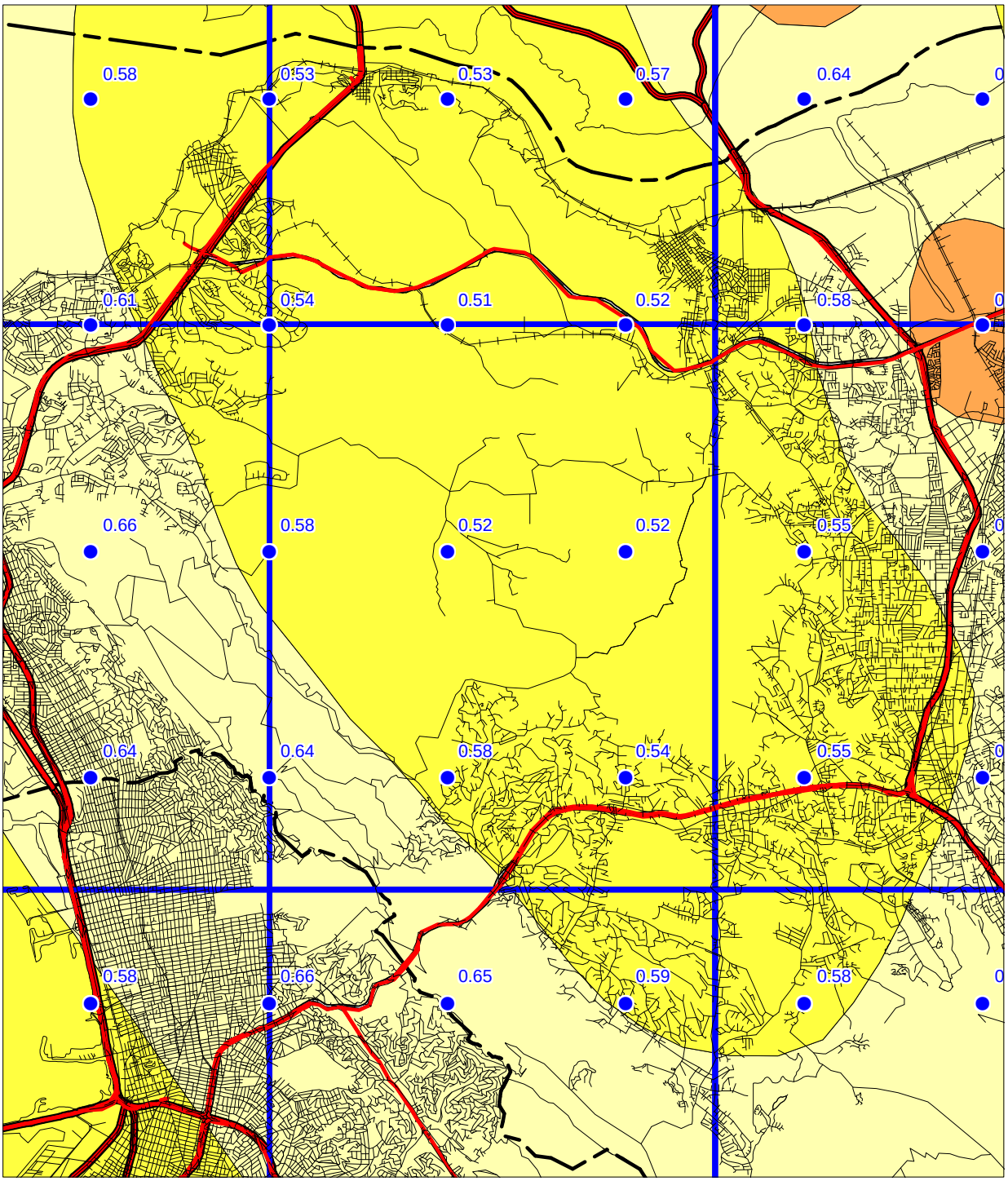
Figure 3.2

BRIONES VALLEY 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
California Geological Survey

Figure 3.3

adjacent 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 percent 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.

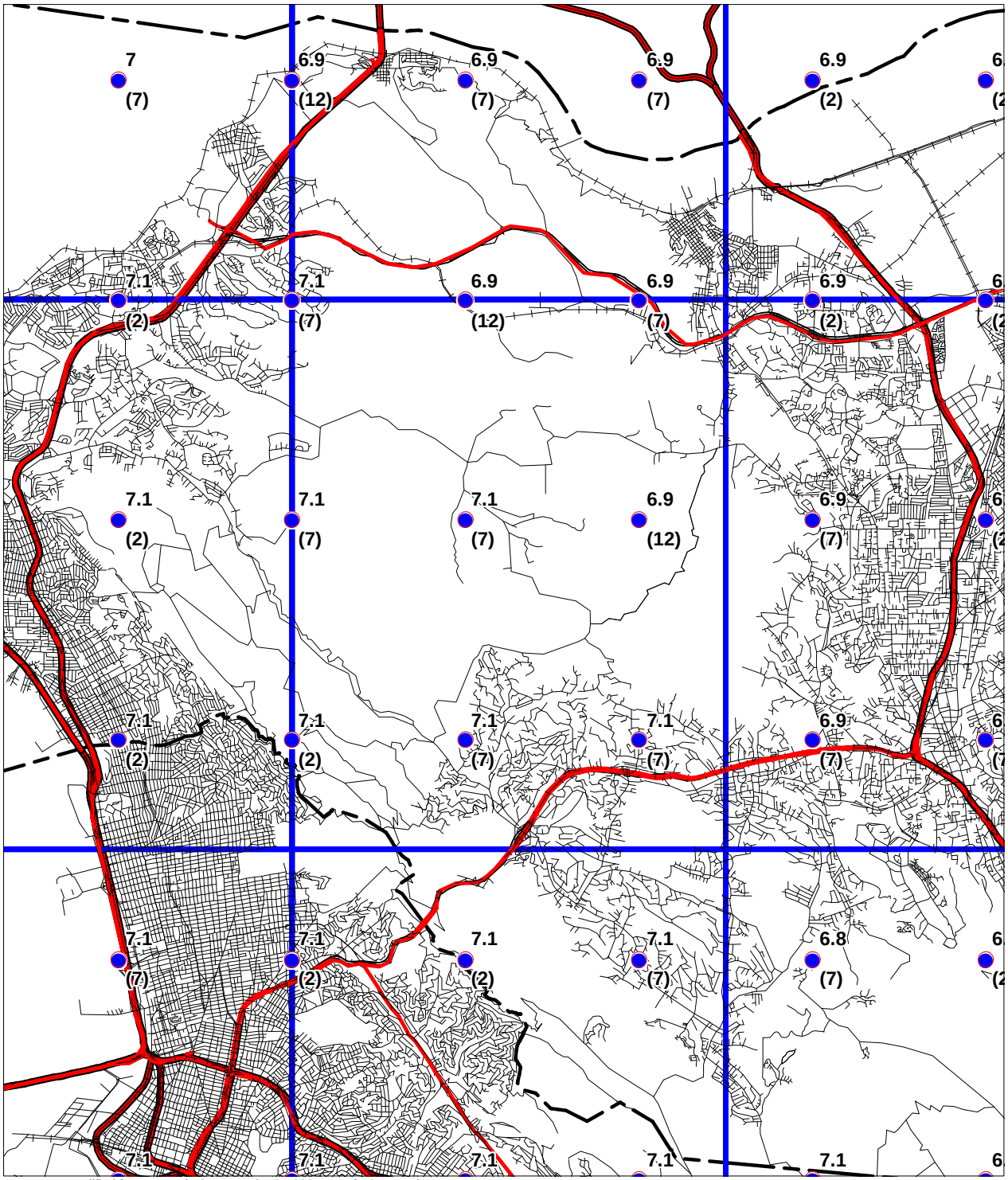
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

BRIONES VALLEY 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 1.5 3
Miles

Department of Conservation
Division of Mines and Geology

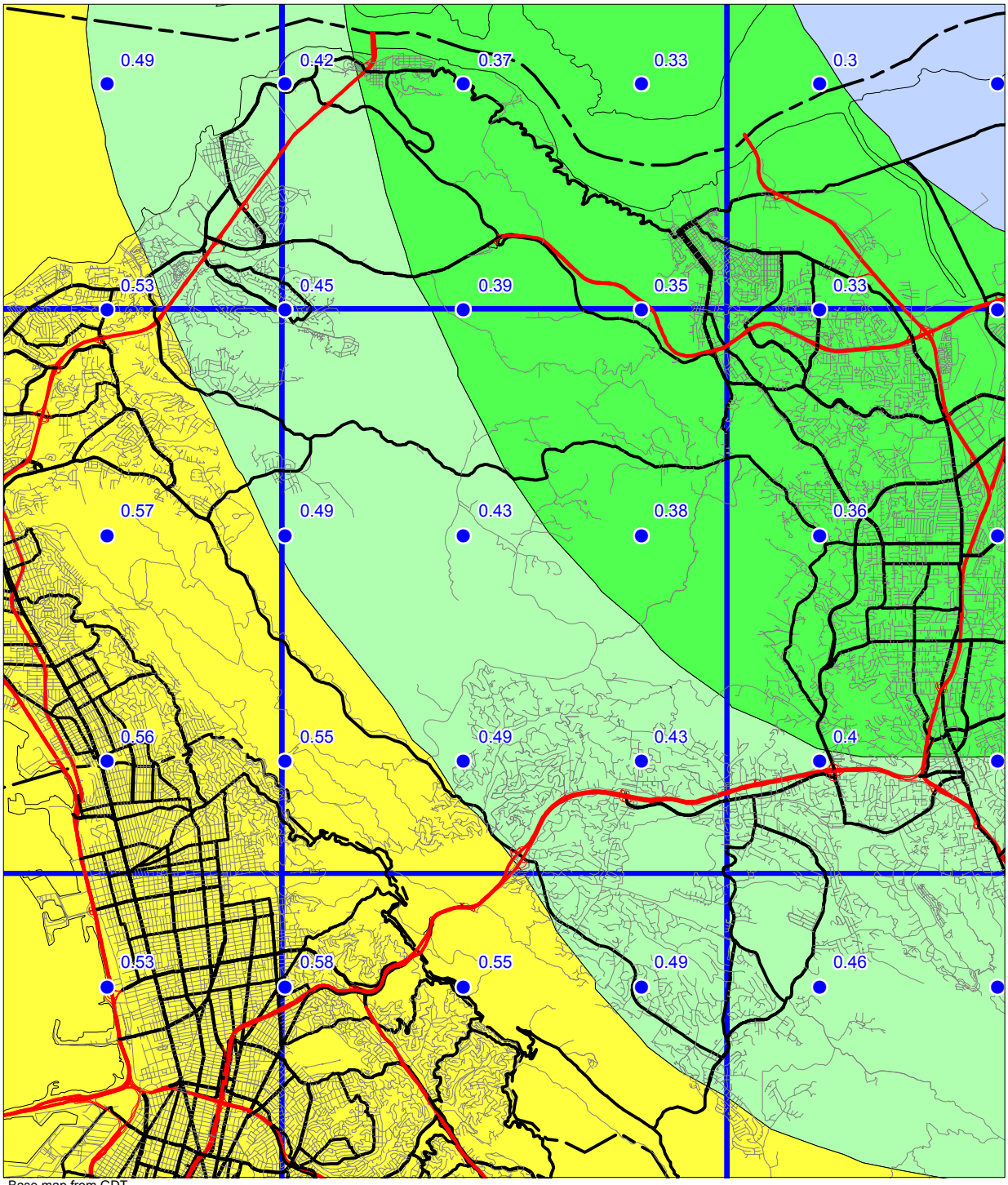
Figure 3.4

BRIONES VALLEY 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 percent 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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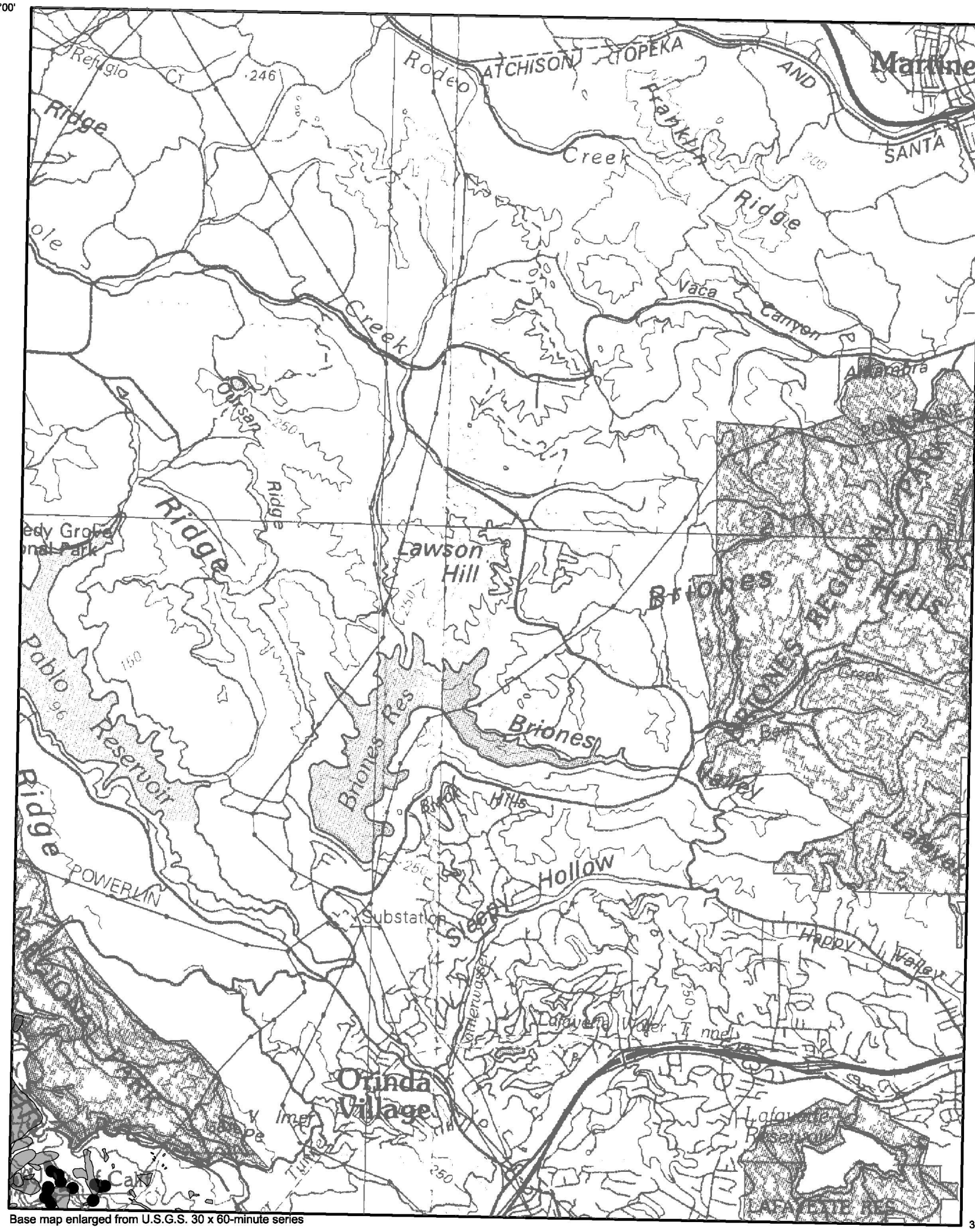

Base map enlarged from U.S.G.S. 30 x 60-minute series

BRIONES VALLEY QUADRANGLE

SCALE
1 .5 0 1 MILE
1000 0 2000 4000 6000 FEET
1 .5 0 1 KILOMETER

N

● Shear test sample location Landslide

Plate 2.1 Landslide inventory and shear test sample locations, Briones Valley 7.5-Minute Quadrangle, California.