SEISMIC HAZARD ZONE REPORT 107

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

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

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ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Valyermo 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 53 square miles at a scale of 1 inch = 2,000 feet.

The Valyermo Quadrangle lies in northeastern Los Angeles County about 20 miles southeast of Palmdale and 37 miles northeast of the Los Angeles Civic Center where the San Gabriel Mountains rise to the south of the Mojave Desert. The San Andreas Fault crosses the center of the quadrangle as a series of aligned trough-like valleys, linear hills, and closed depressions. South of the fault zone is Devils Punchbowl County Park that dramatically displays folded strata. Pinyon Ridge borders the south side of the fault zone in the central and eastern parts of the map area. The San Gabriel Mountains rise to 8,248 feet along the crest of Pleasant View Ridge near the southern boundary. Holcomb Ridge separates the floodplain of Big Rock Creek from the Mojave Desert. The California Aqueduct and scattered ranches and rural homes are on the surface that descends northward toward the Mojave Desert. The Angeles National Forest covers about one third of the quadrangle and there are scattered private land parcels within the national forest.

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 percent probability of exceedance in 50 years.

In the Valyermo Quadrangle the liquefaction zone coincides with Big Rock Creek and Big Rock Wash and alluvial apron areas where, historically, ground water has been within 40 feet of the surface. The deeply dissected terrain in Big Rock Creek canyon, the Devils Punchbowl and the slopes of Pinyon Ridge is within the earthquake-induced landslide hazard zone, which covers about 20 percent of the evaluated portion of the Valyermo 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 (CGS) Internet page: http://www.conservation.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, 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 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/webdocs/sp117.pdf

The Act 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. The Act 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 remains 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 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 potentially liquefiable soils and earthquake-induced landslides in the Valyermo 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By
Elise Mattison, Allan G. Barrows, and Cynthia L. Pridmore

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 developed 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 seismic hazard zones. 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/webdocs/sp117.pdf

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 liquefaction 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 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 liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Valyermo 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which 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 CGS'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 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 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, including areas in the Valyermo 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, 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.

- Ground-water maps constructed to show the historically highest known ground-water levels

- Geotechnical data analyzed to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS 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 SMGB (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 Valyermo Quadrangle consist mainly of alluviated valleys. CGS'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 Valyermo Quadrangle covers about 62 square miles in northeastern Los Angeles County where the San Gabriel Mountains rise from the southern Mojave Desert. The center of the area is 20 miles southeast of Palmdale and 37 miles northeast of the Los Angeles Civic Center. The San Andreas Fault trends northwest across the center of the quadrangle within a rift zone, which consists of a series of aligned trough-like valleys, linear hills, and closed depressions. South of the rift zone near the western boundary is Devils Punchbowl County Park where a well-exposed syncline in Tertiary strata is dramatically displayed. Broad, prominent Pinyon Ridge borders the south side of the rift zone in the central and eastern parts of the map area. The San Gabriel Mountains rise to 8,248 feet along the crest of Pleasant View Ridge along the southern boundary of the quadrangle. North of the rift zone near the Valyermo post office are ranches and the floodplain of Big Rock Creek. Holcomb Ridge separates the floodplain and ranches from the Mojave Desert. Crystalaire Country Club, the California Aqueduct, and scattered ranches and rural homes are on the surface that descends northward toward the Mojave Desert. The lowest elevation in the quadrangle is 3,200 feet in the northwestern corner.

The boundary of the Angeles National Forest cuts across the center of the quadrangle. National forest land covers about 35 percent of the quadrangle. Devils Punchbowl County Park covers less than 2 square miles. The remainder of the land is unincorporated Los Angeles County land. About 86 percent (53 square miles) of the quadrangle, including scattered private land parcels within the national forest, was evaluated for zoning.

Access to the region is via Pearblossom Highway (State Highway 138) along the northern boundary of the quadrangle. Valyermo Road connects Valyermo and the community of Pearblossom west of the quadrangle. East of Big Rock Creek the road becomes Big Pines Highway. Other county roads, including 165th Street East and 204th Street East, also provide access.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that are generally susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. For this evaluation, the Quaternary geologic map of Ponti and Burke (1980) was used for the Antelope Valley part of the quadrangle, and detailed geologic maps of Barrows and others (1985, Plates 1G and 1H) were used for the San Andreas Fault Zone. The Southern California Areal Mapping Project (SCAMP) provided geologic maps from both of these sources in digital form. CGS digitized part of a geologic map by Dibblee (2002) for the portion of the Valyermo Quadrangle south of the detailed strip map along the fault zone.

Note that Plate 1.1 reflects no CGS attempt to modify original mapping or resolve border differences among the various geologic maps. CGS staff addressed such differences only during construction of the liquefaction zone map using techniques and tools such as topography, aerial photography, satellite imagery, and limited fieldwork.

About 40 percent of the Valyermo study area is covered by alluvial deposits of Quaternary age. These Pleistocene through Holocene surficial deposits are summarized in Table 1.1 and discussed below. The remaining area consists of various sedimentary, igneous and metamorphic rock units juxtaposed by complex lateral and thrust faulting.

The bedrock units are discussed in detail in the Earthquake Induced Landslide section of this report (Section 2).

Ponti and Burke (1980) mapped Quaternary units based mainly on relative age (Q1, the oldest; Q7, the youngest) and grain size (f=fine, m=medium, c=coarse, vc=very coarse). Barrows and others (1985) divided Quaternary deposits by age (Qoa for older and Qal for younger) and environment of deposition (Qsc (stream channel), Qf (alluvial fan), and Qp (pond deposits)). In the Valyermo Quadrangle, Dibblee (2002) distinguished younger from older Quaternary deposits (Qa and Qoa, respectively) and designated young Quaternary stream deposits (Qg) and valley alluvium (Qa).

Quaternary geologic units of Antelope Valley

The oldest Quaternary units mapped by Ponti and Burke (1980) in the Valyermo Quadrangle consist of moderately to severely dissected alluvial fans and weakly consolidated, poorly to moderately sorted, high terrace deposits containing clasts that indicate a source different from that of nearby modern channels. These exposures are mapped in the northeast quarter of the quadrangle (Q1vc, Q2vc, Q2c, Q3c), and in the north central part, in the vicinity of 175th Street East (Q3vc). Undifferentiated terrace and fan deposits (Q1-3c) are mapped along Big Rock Wash and west of Big Rock Wash, at the western boundary of the quadrangle. Finer-grained facies (-f, -m) are buried by younger deposits.

Later Pleistocene units mapped by Ponti and Burke (1980) in the Valyermo Quadrangle consist of slightly dissected alluvial fans, unconsolidated, moderately to well sorted, intermediate terrace deposits, and dissected colluvial aprons. Only one exposure of Q4c is mapped, east of 204th Street East, between heavily dissected fans of Q1c. Three exposures of Q5c are in the same vicinity. Scattered terrace and fan material on the fringes of older deposits are mapped as undifferentiated deposits (Q4-5c).

Large areas of unconsolidated, poorly to well sorted, medium- to coarse-grained deposits of late Pleistocene and early Holocene age cover much of the Antelope Valley part of the Valyermo Quadrangle (Ponti and Burke, 1980). These include low-elevation terrace and young alluvial fan material (Q6c, Q6m) and floodplain deposits next to modern channels (Q7c, Q7m).

The youngest Antelope Valley units mapped by Ponti and Burke (1980) in the Valyermo Quadrangle are unconsolidated, poorly sorted, flash-flood sediments deposited in modern stream channels. The very coarse facies (Qsvc) are generally upstream from the coarse facies (Qsc).

Quaternary geologic units south of Antelope Valley

The Harold Formation (Qh), the oldest Quaternary unit north of the San Andreas Fault, consists of generally fine-grained, silty to sandy, moderately well-stratified fluvial, alluvial fan, and playa deposits with abundant caliche. Barrows and others (1985) mapped a distinctive variety of Harold Formation near St. Andrews Priory, near the western boundary of the quadrangle. This unit, called the schist and sandstone-clast member (Qhs), contains clasts of Pelona Schist, granite, and sandstone pebbles from the San Francisquito Formation.

Shoemaker Gravel (Qs), of Pleistocene age, is the oldest unit in a series of late Quaternary coarse alluvial gravels north of the San Andreas Fault that were derived from the uplifted terrain south of the San Andreas Fault. Shoemaker Gravel, named for Shoemaker Canyon in the center of the quadrangle (Noble, 1954), is typically coarse, locally bouldery, alluvial fan debris with abundant leucocratic granitic rocks, varieties of Lowe Granodiorite, and recycled volcanic cobbles and pebbles from Punchbowl Formation conglomeratic sandstone. It is weakly to moderately consolidated and poorly sorted.

Other coarse boulder gravel deposits that texturally resemble Shoemaker Gravel, but are closer to their source terranes and, thus, younger, occur on the northern side of the San Andreas Fault. Although similar in appearance to Qs, the other boulder gravels are compositionally different and mapped separately. Boulder gravel of Big Rock Creek (Qbb) is found only east of Big Rock Creek where it crosses the fault zone, except for a patch on top of the highly faulted hill within the fault zone just west of the creek crossing. Boulders, up to 2.5 m in diameter, and cobbles in Qbb were derived from the area drained by modern Big Rock Creek. On the western side of the quadrangle near St. Andrews Priory is a very similar and probably contemporary very coarse boulder gravel (Qbp) derived from the Pallett Creek drainage. Qbp is found only west of Big Rock Creek.

A variety of alluvial deposits younger than the boulder gravels have also been mapped by clast composition (Barrows and others, 1985). These include older alluvium with marble clasts (Qoam), older alluvium with sandstone clasts (Qoas), and older alluvium of Holcomb Ridge (Qoah). These units are typically thin and overlie tilted Shoemaker Gravel deposits or pre-Quaternary units within the northern part of the quadrangle. Abundant remnants of a dissected apron of unconsolidated to moderately consolidated older alluvium (Qoa) deposits cover the older units east of Big Rock Creek. Only a small area of alluvial boulder gravel or fanglomerate (Qog) mapped by Dibblee (2002) is included in Plate 1.1 (shown as a wedge of Qo), at the eastern boundary of the quadrangle, in the fault zone.

A variety of Quaternary alluvial deposits rests unconformably upon Tertiary sedimentary and pre-Tertiary basement rocks in the Valyermo Quadrangle. Within the San Andreas Fault Zone, at the head of Shoemaker Canyon, are dissected remnants of older alluvial rubble derived from the dioritic rocks of Pinyon Ridge (Qor). These deposits are covered in places by dissected older alluvium (Qoa). A large deposit of older alluvial fan material (Qof), which once spread across the entire area now called the Devils Punchbowl, remains as a broad apron that extends beyond the western boundary of the quadrangle. Older terrace deposits (Qot) were mapped by Barrows and others (1985) north of Big Rock Creek and at the confluence of Big Rock and Pallett creeks. Younger (modern) deposits consist of alluvium (Qal), slope wash (Qsw), ponded alluvium (Qpa) in the fault zone, alluvial fan (Qf), stream terrace (Qt) and stream-channel deposits (Qsc).

South of the fault zone, Dibblee (2002) mapped stream channel gravel and sand (Qg) along Big Rock Creek, and alluvial fans (Qf) in Fenner Canyon and along slopes along Big Rock Creek. Dibblee's (2002) alluvial gravel, sand and clay of valley areas (Qa) is in Holcomb Canyon, and older alluvial gravel and sand (Qoa) is exposed west of Devils Punchbowl, south of the Qof mapped by Barrows and others (1985).

Map Unit				Environment or Type of Deposit	Age
Plate 1.1 (this report)	Ponti and Burke (1980)	Barrows and others (1985)	Dibblee (2002)		
Qy	**Q6, Q7, Qsc, Qsvc**	**Qal, Qf, Qpa, Qsw, Qt, af**	**Qa, Qg, Qf**	fan, stream, floodplain, pond, terrace, slope, artificial fill	Holocene and latest Pleistocene
Qo	**Q4, Q5**	**Qoa, Qoah, Qoas, Qoam, Qof, Qor, Qot, Qbb, Qbp**	**Qoa, Qog**	fan, terrace, slope, stream	late Pleistocene
Qo	**Q1, Q2, Q3**	**Qs, Qh, Qhs**	**Qoa, Qog**	fan, stream, terrace	middle to late Pleistocene

Table 1.1. Quaternary Map Units of the Valyermo Quadrangle.

Structural Geology

The dominant structural feature of the Valyermo Quadrangle, the San Andreas Fault Zone, juxtaposes dissimilar rock assemblages. Topographically, the San Andreas Fault lies generally within the San Andreas Rift Zone, which is defined by linear ridges, troughs such as Shoemaker Canyon and the Caldwell Lake depression, and deflected and offset drainage courses. These features have resulted from numerous surface-faulting earthquakes in late Quaternary time. North of the fault, Holcomb Ridge rises above the floodplain of Big Rock Creek and blocks the view of Antelope Valley from Valyermo. South of the San Andreas Fault the terrain is mountainous and deeply dissected by Big Rock Creek. The Punchbowl Fault Zone, which lies 2 to 2.5 miles south of the San Andreas Fault (Noble, 1954; Dibblee, 2002), consists of an intensely sheared and red-stained band of rocks along the San Gabriel Mountains. They rise abruptly toward Pleasant View Ridge, which is mostly within the Angeles National Forest and outside of the area evaluated for zoning in the current study. Deformation of the Tertiary sedimentary strata in the spectacular Punchbowl Syncline resulted from movement along the Punchbowl Fault prior to the development of the modern San Andreas Fault. The Northern Nadeau Fault, in the Juniper Hills Quadrangle (Barrows and others, 1985) to the west, merges with the San Andreas Fault near Pallet Creek and, therefore, is not in the Valyermo Quadrangle. The Southern Nadeau-Holmes Fault may be cut off by the San Andreas Fault near Sandrock Creek.

ENGINEERING GEOLOGY

As stated above, soils that are generally susceptible to liquefaction are mainly late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Saturated, loose sandy and silty soils are most susceptible to liquefaction. Lithologic descriptions and soil test results reported in geotechnical borehole logs provide valuable information regarding subsurface geology, ground-water levels, and the engineering characteristics of sedimentary deposits.

Of particular value in liquefaction evaluations are logs that report the results of downhole standard penetration tests (SPTs), which provide a uniform measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) 1 foot into the soil at the bottom of a borehole at chosen intervals while drilling. The driving force is provided by dropping a 140-pound hammer 30 inches. The SPT method is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differs from that specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common-reference effective-overburden pressure of 1 atmosphere (approximately 1 ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations are made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

During the initial stages of this investigation, CGS obtained logs of trenches and geotechnical boreholes from Antelope Valley localities. Staff collected the logs from the files of the California Department of Transportation; the California Department of Water Resources; the Los Angeles County Public Works Department; Earth Systems, Southern California; and Leighton and Associates, Inc. Most of the logs collected for the Valyermo Quadrangle are from boreholes along the California Aqueduct. However, only a few are from holes drilled through potentially saturated material.

Borehole logs and Quaternary geology maps indicate that much of area between the San Andreas and Holcomb Ridge faults is covered by young, loose to moderately dense, sandy and silty sediments. Major stream drainages, including Pallett Creek and Big Rock Wash, contain young, loose sediments. North of Holcomb Ridge, Holocene and Pleistocene gravel, sand and clay alluvium fans spread into Antelope Valley.

Geologic Map Unit*	Material	Consistency	Age	Liquefaction Susceptibility**
af, Qsc, Qsvc, Qg, Qa	clay, silt, sand, and gravel	very loose	latest Holocene	high
Q6, Q7	sand and gravel	loose	Holocene and late Pleistocene	high
Qal, Qf, Qpa, Qsw, Qt	gravel, sand, and silt	loose to moderately dense	Holocene and late Pleistocene	high to moderate
Q4, Q5, Qoa, Qoah, Qoah, Qoam, Qof, Qor, Qot, Qbb, Qbp	gravel, sand, silt, clay, breccia	dense	Pleistocene	low
Q1, Q2, Q3, Qs, Qh, Qhs, Qoa, Qog	gravel, sand, silt	dense	Pleistocene	low

*see Table 1.1 for map unit correlations between Ponti and Burke (1980), Barrows and others (1985), and Dibblee (2002).
**when saturated

Table 1.2. Quaternary Map Units Used in the Valyermo 7.5-Minute Quadrangle and Their Geotechnical Characteristics and Liquefaction Susceptibility

GROUND WATER

An essential element in evaluating liquefaction susceptibility is the determination of the depth at which soils are saturated by ground water. Saturation reduces the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). For zoning purposes, "near surface deposits" include those sediments between 0 and 40 feet deep, an interval derived from item 4a of the SMGB criteria for delineating seismic hazard zones in California (DOC, 2000; also see Criteria for Zoning section of this report). Liquefaction evaluations, therefore, concentrate on areas where investigations indicate that young Quaternary sediments might be saturated within 40 feet of the ground surface. Unfortunately, unpredictable and dramatic fluctuations in ground water caused by natural processes and human activities make it impossible to anticipate water levels at the time of future earthquakes. For that reason, CGS uses historically shallowest ground-water levels for evaluating and zoning liquefaction potential. This approach assumes that even in areas where levels are presently significantly deeper, ground water could return to historically high levels. This, in fact, has occurred in basins where water-importing urbanized areas have replaced vast farm and orchard lands that were characterized by substantial ground-water withdrawal (*e.g.* Simi Valley, Ventura County) as well as in basins where large-scale ground-water recharge programs are employed.

Plate 1.2 depicts historically shallowest depths to ground water in Valyermo Quadrangle valleys. Historically high ground-water levels throughout most of the quadrangle are generally deeper than 40 feet. Exceptions are: 1) active washes that extend out onto the Antelope Valley floor from the San Gabriel Mountains, where ground water is thought to historically have been within 40 feet of the surface; 2) alluviated areas between Holcomb Ridge and the San Andreas Fault, including the Pallet Creek area, where ground water was measured at 19 feet; and 3) restricted canyons where ground water is assumed to be during wet periods.

Sources of ground-water data reviewed for this report include Galloway and others (1998), Bloyd (1967), Durbin (1978), Duell (1987), Leighton and Associates (1990), Templin and others (1995), Carlson and others (1998), Carlson and Phillips (1998), and California Department of Water Resources (1966; 2003).

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), who 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. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (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.

CGS'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.

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 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Valyermo Quadrangle, PGAs ranging from 0.55 to 0.82g, resulting from a predominant earthquake of magnitude 7.8, were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data collected by staff to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Although 18 geotechnical borehole logs were collected for the Valyermo Quadrangle study (Plate 1.2), few contained reliable penetration test data so liquefaction analyses were not performed.

When data are available, CGS employs the Seed-Idriss Simplified Procedure to calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site-specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were recorded. Typically, multiple tests are performed at prescribed intervals in each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated within the upper 40 feet of the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

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 SMGB (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 percent 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 percent 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 percent 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 Valyermo Quadrangle is summarized below.

Areas of Past Liquefaction

Documentation of historical liquefaction in the Valyermo Quadrangle was not found during this study. Sieh (1978, 1984), however, documented sandblows and other evidence of prehistoric liquefaction in trenches along the trace of the San Andreas Fault at Pallett Creek just west of the quadrangle boundary in the Juniper Hills Quadrangle.

Artificial Fills

Areas of artificial fill large enough to show at the scale of mapping are aqueduct embankments and road foundations. Because these are considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying deposits. Non-engineered fills are commonly loose and uncompacted, and the material varies in size and type.

Areas with Sufficient Existing Geotechnical Data

CGS staff did not find sufficient existing geotechnical data within any area of the Valyermo Quadrangle. Soil descriptions indicate that near surface young Quaternary sediments (Q6 and Q7 of Ponti and Burke, 1980) in Antelope Valley generally contain loose sand and gravel, material that could liquefy where saturated under historically shallowest ground-water conditions presented on Plate 1.2. These areas are designated zones of required investigation on the Seismic Hazard Zone Map of the Valyermo Quadrangle.

Areas with Insufficient Existing Geotechnical Data

Although geotechnical data available within the study area are insufficient for evaluating Quaternary deposits for liquefaction, logged lithology in boreholes and water wells, and data from drilling in similar geologic environments in adjacent quadrangles, indicate that young Quaternary deposits in Antelope Valley, the San Andreas Rift Zone, and stream canyons of the San Gabriel Mountains contain loose, sandy material. Such deposits could liquefy where saturated within 40 feet of the surface under historically shallowest ground-water conditions presented on Plate 1.2. Therefore, these areas are designated zones of required investigation on the Seismic Hazard Zone Map of the Valyermo Quadrangle.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Valyermo 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) [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/webdocs/sp117.pdf

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 Valyermo 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking) complete 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.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 Valyermo 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. 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 Valyermo 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 Valyermo 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 Valyermo Quadrangle covers about 62 square miles in northeastern Los Angeles County where the San Gabriel Mountains rise to the south of the Mojave Desert. The center of the area is 20 miles southeast of Palmdale and 37 miles northeast of the Los Angeles Civic Center. The San Andreas Fault trends northwesterly across the center of the quadrangle within a rift zone, which consists of a series of aligned trough-like valleys, linear hills, and closed depressions. South of the rift zone near the western boundary is Devils Punchbowl County Park where a well-exposed syncline in Tertiary strata is dramatically displayed. Broad, prominent Pinyon Ridge borders the south side of the rift zone in the central and eastern parts of the map area. The San Gabriel Mountains rise to 8,248 feet along the crest of Pleasant View Ridge on the southern boundary of the quadrangle. North of the rift zone near the Valyermo Post Office are ranches and the floodplain of Big Rock Creek. Holcomb Ridge separates the floodplain and ranches from the Mojave Desert. Crystalaire Country Club, the California Aqueduct, and scattered ranches and rural homes are on the surface that descends northward toward the Mojave Desert. The lowest point in the quadrangle is 3,200 feet in the northwestern corner.

The boundary of the Angeles National Forest cuts across the center of the quadrangle. National forest land covers about 35 percent of the quadrangle. Devils Punchbowl County Park covers less than 2 square miles. The remainder of the land is unincorporated Los Angeles County land. Due to the presence of scattered private land parcels within the national forest about 86 percent (53 square miles) of the quadrangle was evaluated for Seismic Hazard Zones.

Access to the region is via Pearblossom Highway (State Highway 138) along the northern boundary of the quadrangle. Valyermo Road connects Valyermo and the community of Pearblossom west of the quadrangle. East of Big Rock Creek the road becomes Big Pines Highway. Other county roads, including 165th Street East and 204th Street East also provide access.

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 Valyermo Quadrangle, 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 1957 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

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

GEOLOGY

Bedrock and Surficial Geology

The geologic map used as background geology for the Valyermo Quadrangle was prepared from three sources. Detailed geologic maps of the San Andreas Fault Zone, including the segment that traverses the Valyermo Quadrangle, were prepared by Barrows and others (1985, Plates 1G and 1H). This is the primary source of the data in the background geologic map. Ponti and Burke (1980) mapped the Quaternary geology of eastern Antelope Valley and vicinity, including the northern part of the Valyermo Quadrangle. The pre-Quaternary rocks are generalized on the Ponti and Burke (1980) map, which was used to fill in the northeastern third of the complied geologic map. Geologic maps from both of the above-mentioned sources were digitized by the Southern California Areal Mapping Project [SCAMP]. Part of a geologic map by Dibblee (2002) was digitized by CGS to fill in the portion of the Valyermo Quadrangle south of the detailed strip map along the fault zone by Barrows and others (1985). During the search for landslides in the field observations were made of exposures, aspects of weathering, and general surface expression of the geologic units.

Barrows and others (1985) discussed the geology of the Valyermo area in detail. Because of the contrast in the geologic framework and rock assemblages on opposite sides of the San Andreas Fault, the descriptions of the geologic units in this region will be discussed separately.

Geologic units north of the San Andreas Fault

Widely exposed on Holcomb Ridge and other hills north of the San Andreas Fault is medium- to coarse-grained buff-weathering quartz monzonite to gneissic granodiorite that comprises Holcomb Quartz Monzonite (hqm). Holcomb Quartz Monzonite in the eastern part of the quadrangle near Largo Vista intrudes a well-foliated, fine- to medium-grained, dark gray, thinly laminated biotite quartzo-feldspathic gneiss (bgn) with marble and quartzite layers. Long tabular inclusions of gray to white foliated graphitic marble and calc-silicate rocks (m) also occur within hqm on Holcomb Ridge. Black dioritic gneiss and hornblendite (hdgn) with gabbro pegmatite bands occurs near the eastern boundary east of Mile High. Slivers of white, crumbly, microbreccia of crushed granitic rocks (grc) are poorly exposed along the Star Peak Shear Zone (Barrows and Others, 1985, Plate 1H) north of Caldwell Lake. In the northeastern portion of the quadrangle compiled from Ponti and Burke (1980) the igneous and metamorphic rocks are labeled gr-m.

The only Tertiary unit north of the San Andreas Fault is the Juniper Hills Formation of probable Pliocene age. Undifferentiated Juniper Hills Formation (TQjh) is predominantly white, well-consolidated, pebbly to cobbly, coarse arkosic sandstone and pebble conglomerate with a variety of clasts from recognizable and/or non-recognizable sources (Barrows and others, 1985). TQjh is mostly found close to faults and, consequently, is sheared with fractured and offset pebbles and cobbles. The largest exposure of TQjh occurs north of the Star Peak Shear Zone where it rests uncomformably upon biotite gneiss (bgn) or borders the fault-bound septum of crushed granite mentioned above. Small exposures of the distinctive breccia member (TQjhb) the formation were mapped east of Mountain Brook Ranch. TQjhb is a white to pink arkosic sedimentary breccia that has the appearance of crushed granite and granite pegmatite.

The oldest Quaternary alluvial deposits on the northern side of the San Andreas Fault comprise the Harold Formation (Qh). Harold Formation consists of generally fine-grained, silty to sandy, moderately well-stratified fluvial, alluvial fan, and playa deposits with abundant caliche. A distinctive variety of Harold Formation was mapped separately by Barrows and others (1985) near St. Andrews Priory. This unit, called the schist and sandstone-clast member (Qhs), contains clasts of Pelona Schist, granite, and pebbles of San Francisquito Formation sandstone.

Shoemaker Gravel (Qs) of Pleistocene age is the oldest unit in a series of late Quaternary coarse alluvial gravels derived from the uplifted terrain south of the San Andreas Fault that are scattered across the terrain on the northern side of the San Andreas Fault. Shoemaker Gravel, named for Shoemaker Canyon in the center of the quadrangle (Noble, 1954), is typically coarse, locally bouldery, alluvial fan debris with abundant leucocratic granitic rocks, varieties of Lowe Granodiorite, and recycled volcanic cobbles and pebbles from Punchbowl Formation conglomeratic sandstone. It is weakly to moderately consolidated and poorly sorted.

Other coarse boulder gravel deposits that texturally resemble Shoemaker Gravel, but are closer to their source terranes and, thus, younger, occur on the northern side of the San Andreas Fault. Although similar in appearance to Qs the other boulder gravels are compositionally different and mapped separately. Boulder gravel of Big Rock Creek (Qbb) is only found east of where modern Big Rock Creek crosses the fault zone except for a patch on top of the highly faulted hill within the fault zone just west of the creek crossing. Boulders, up to 2.5 m in diameter, and cobbles in Qbb were derived from the area drained by modern Big Rock Creek. On the western side of the quadrangle near St. Andrews Priory is a very similar and probably contemporary very coarse boulder gravel (Qbp) derived from the Pallett Creek drainage. Qbp is only found west of Big Rock Creek.

A variety of older alluvial deposits, younger than the boulder gravels, have also been mapped on the basis of their contained clasts in the Valyermo Quadrangle (Barrows and others, 1985). These include older alluvium with marble clasts (Qoam), older alluvium with sandstone clasts (Qoas), and older alluvium of Holcomb Ridge (Qoah). These units are typically thin and overlie tilted Shoemaker Gravel deposits or pre-Quaternary units within the northern part of the quadrangle. Abundant remnants of a dissected apron of unconsolidated to moderately consolidated older alluvium (Qoa) deposits cover the older units east of Big Rock Creek.

Other than the stream channel deposits (Qsc) in Big Rock Creek much of the area in the northern part of the quadrangle is covered by modern alluvium (Qal) and, locally, on the slopes of hills of exposed bedrock slope wash (Qsw) or young alluvial fan (Qf) deposits. The alluvium is part of a vast apron that extends out into the Antelope Valley. Units in the portion if the geologic map compiled from Ponti and Burke (1980) include a variety of late Quaternary alluvial units including Q1vc, Q1-3c, Q2c, Q2vc, Q3c, Q4-5c, Q5c, Q6c, Q6m, Q7m and Q7vc. The earliest unit has the lowest number and m means medium-grained, c means coarse and vc means very coarse sediments.

Geologic units south of the San Andreas Fault

The large variety of basement rock types in the Valyermo Quadrangle reflects the complicated pre-Cenozoic history of intrusion and metamorphism of the San Gabriel Mountains. Furthermore, disruption of the basement complex rocks by episodes of large-displacement lateral faulting and, locally, thrust faulting has added to the complexity of the regional geologic setting (Noble, 1954; Barrows and others, 1985; Dibblee, 2002). The Punchbowl Fault, which is subparallel to the San Andreas Fault and about 2 miles south, defines the southern boundary of a band of complex structures and various rock units between the major faults. The most spectacular feature is the Devils Punchbowl; a large truncated synclinal fold in Tertiary sedimentary strata.

South of the Punchbowl Fault in the portion of the geologic map compiled from Dibblee (2002) the San Gabriel Mountains contain gray, fractured quartzo-feldspathic gneissic rocks (gn) and, locally, highly sheared, cataclastic gneiss (cgn). These rocks are intruded by or in fault contact with massive gray medium-grained quartz diorite (qd) and quartz diorite containing granite and aplite intrusions (qdc). In the Punchbowl Fault Zone the quartz diorite is intensely crushed (cqd). Younger gray to aplitic white granite and/or quartz monzonite (gr) has intruded the older basement rocks near the southwestern corner of the map area.

Silver to dark gray, fine- to medium-grained, foliated to massive quartz muscovite Pelona Schist (pls) (or ps as mapped by Dibblee, 2002) makes up the part of Blue Ridge that extends into the eastern side of the quadrangle. Pelona Schist is bordered on the north by the Fenner Fault and on the south by the Punchbowl Fault Zone. Pinyon Ridge lies between Fenner Canyon and the San Andreas Fault in the eastern half of the quadrangle. It consists of predominantly gray to greenish-black, massive to gneissic, medium-grained hornblende quartz diorite (hqd). Hornblende quartz diorite is also exposed near the western side of the quadrangle where it lies between the Holmes Fault and the San Andreas Fault. South of the portion of the geologic map compiled from the strip map of Barrows and others (1985), Dibblee (2002) mapped rocks similar to hqd as mostly granodiorite (grdi).

Paleocene marine sedimentary strata of the San Francisquito Formation (Tsf) rest depositionally upon hornblende quartz diorite (hqd) on Pinyon Ridge. Tsf is locally overridden near the western boundary by hornblende quartz diorite along the Holmes Fault. The San Francisquito Formation is comprised of several members that reflect depositional conditions and, thus, the texture of the deposits. The basal boulder unit (Tsfb) is locally exposed in a few places on the top of Pinyon Ridge. Tsfb is an unusual bouldery shale with very well rounded, highly polished boulders of gneiss and granitic rocks up to 4 m in diameter in a shale or sandstone matrix.

The shale facies (Tsfs) of the San Francisquito Formation is widespread on Pinyon Ridge. It consists of dark brown to black, thin-bedded shale and argillite with abundant, resistant, ellipsoidal mudball concretions, nodules or lenses. Tsfs is locally gypsiferous and tightly folded. San Francisquito Formation conglomerate facies (Tsfc) layers are present near the western quadrangle boundary. Tsfc beds are up to 4 m thick with very resistant, well-rounded pebbles and cobbles of a large variety of igneous and metavolcanic rocks. Tsfc clasts are typically polished from tectonic movements near faults, especially the Holmes Creek Fault. The bulk of the San Francisquito Formation in the Valyermo Quadrangle is mapped as undifferentiated (Tsf) rocks that are predominantly massive to moderately thick-bedded marine sandstone with interbeds of pebbly to cobbly sandstone, conglomerate and shale. Tsf sandstone is yellowish brown to rusty orange brown weathering, resistant, medium to coarse grained, gritty, and arkosic with local concentrations of fossils. In that portion of the composite geologic map compiled from the map by Dibblee (2002) the San Francisquito Formation east of the Devils Punchbowl consists of sandstone (Tsfs), conglomerate (Tsfc) and clay shale (Tsf) subunits.

Unconformably resting upon San Francisquito Formation marine strata are upper Miocene to lower Pliocene non-marine pebbly arkosic rocks of the Punchbowl Formation (Noble, 1954; Barrows and others, 1985). Locally exposed along the contact is the basal breccia member (Tpb) of the Punchbowl Formation. Tpb is a dark red megabreccia composed exclusively of coarse, angular, very poorly sorted debris of San Francisquito Formation sandstone and conglomerate blocks up to 1.5 m in diameter. Most of the steeply tilted beds and "flatirons' in the Devils Punchbowl Syncline consist of Punchbowl Formation (Tp) that is predominantly grayish white to pinkish, well-cemented, coarse, arkosic sandstone and fluvial pebble, cobble and boulder gravel. Clasts in Tp sandstone beds include a variety of igneous rocks, ranging from white granite to dark foliated diorite, and San Francisquito Formation sandstone and tough cobbles recycled from San Francisquito Formation conglomerate beds. Although apparently conformable upon Punchbowl Formation (Tp) rocks, as described above, the volcanic-clast member (Tpv) reflects an abrupt change in source area or direction of drainage (Barrows and others, 1985). The volcanic-clast member of the Punchbowl Formation (Tpv) is a well-indurated, well-stratified, fluvial, white to pink, coarse arkosic pebbly to cobbly sandstone with brown, thin silty sandstone interlayers. Clasts are predominantly light-colored granitic rocks and as much as 40 percent multi-colored, unmetamorphosed volcanic rocks ranging from rhyolite to andesite (as opposed to tough, altered recycled Tsf volcanic cobbles). In the portion of the composite geologic map compiled from the map by Dibblee (2002) the Punchbowl Formation consists of conglomerate (Tpc), sandstone (Tps) and red-stained conglomerate (Tprc) adjacent to the Punchbowl Fault Zone along the southern margin of the area evaluated for zoning.

A variety of Quaternary alluvial deposits rests unconformably upon Tertiary sedimentary and pre-Tertiary basement rocks in the Valyermo Quadrangle. Near where Big Rock Creek crosses the San Andreas Fault Zone there are deposits of a very coarse gravel that contains a variety of boulders and cobbles derived from rocks that are present in the Big Rock Creek drainage. A prominent hill of this boulder gravel of Big Rock Creek (Qbb) lies west of the Creek within the fault zone and several remnants lie on the slopes east of the creek crossing. Within the San Andreas Fault Zone at the head of Shoemaker Canyon are dissected remnants of older alluvial rubble derived from the dioritic rocks of Pinyon Ridge (Qor). These deposits are covered in places by dissected older alluvium (Qoa). A large deposit of older alluvial fan material (Qof), which once spread across the entire area now called the Devils Punchbowl, remains as a broad apron that extends beyond the western boundary of the quadrangle. Younger (modern) deposits consist of alluvium (Qal), slope wash (Qsw), ponded alluvium (Qpa) in the fault zone, alluvial fan (Qf), stream terrace (Qt) and stream-channel deposits (Qsc).

Structural Geology

The dominant structural feature within the Valyermo Quadrangle is the San Andreas Fault Zone, which crosses the entire quadrangle and separates geologic terranes with dissimilar rock assemblages. Topographically, the San Andreas Fault lies generally within the San Andreas Rift Zone, which is defined by linear ridges, troughs such as Shoemaker Canyon and the Caldwell Lake depression, and deflected and offset drainage courses. These features have resulted from numerous surface-faulting earthquakes in late Quaternary time. North of the fault Holcomb Ridge rises above the floodplain of Big Rock Creek and blocks the view of the Antelope Valley from Valyermo. South of the San Andreas Fault the terrain is mountainous and deeply dissected by Big Rock Creek. The Punchbowl Fault Zone, which lies about 2 to 2.5 miles south of the San Andreas Fault (Noble, 1954; Dibblee, 2002), consists of an intensely sheared and red-stained band of rocks along the San Gabriel Mountains. They rise abruptly toward Pleasant View Ridge, which is mostly within the Angeles National Forest and outside of the area evaluated for zoning in the current study. Deformation of the Tertiary sedimentary strata within the spectacular Punchbowl Syncline resulted from movement along the Punchbowl Fault prior to the development of the modern San Andreas Fault. The Northern Nadeau Fault within the Juniper Hills Quadrangle (Barrows and others, 1985) to the west merges with the San Andreas Fault near Pallet Creek and, therefore, doesn't enter the Valyermo Quadrangle. The Southern Nadeau-Holmes Fault may be cut off by the San Andreas Fault near Sandrock Creek.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Valyermo Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published landslide mapping. 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 landslide zoning as described later in this report. 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.

Several landslides are mapped in the Valyermo Quadrangle and most are debris slides and rock slides that occur in the San Francisquito Formation. Relatively older and highly eroded rock slides are also mapped in the quartz diorite. A rotational rock slide occurs in the older alluvium (Q2vc) near Panorama Road in the east-central portion of the quadrangle.

Because it is not within the scope of the Act to review and monitor grading practices to ensure past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

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. Five shear tests were found for the Valyermo Quadrangle, collected from the Los Angeles County Public Works Department. Shear tests from the Ritter Ridge, Palmdale, Littlerock, and Juniper Hills quadrangles were used to characterize units with no test data and augment units with minimal data.

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 or median) phi values for each geologic map unit and corresponding strength groups are summarized in Table 2.1. For each geologic strength group (Table 2.2) in the map area, the average shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Quaternary units were found to be consistently medium- to very coarse-grained and, where tested, were found to have very similar shear strength characteristics. For these reasons all Quaternary alluvial deposits in the Valyermo Quadrangle were combined and treated as one geological unit.

Existing Landslides

As will be 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. For the Valyermo Quadrangle, no shear tests of landslide slip surface materials were available. A phi value of 16 degrees was derived from shear tests collected in the Mint Canyon Quadrangle to the west and was judged to be representative of the relatively few landslides in the study area.

VALYERMO 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	gr	41	34/35	35	394/320	bgn, cqd	35
	hqm	11	36			gn, grc	
	ps	10	35			grdi	
	qd	1	38			gr-m, hdg, hqd, hdgn, m ps, qdc,	
GROUP 2	Q*	66	30/31	30/31	202/150	Q**, af TQjh,TQjhb, Tp, Tpb Tpc, Tprc Tps, Tpv Tsf, Tsfb Tsfc, Tsfs	30
GROUP 3	Qls						16

Q* = Q4-5c, Qf, Qoa, Qof, Qsc, Qsw

Q** = Q1-3c, Q1vc, Q2c, Q2vc, Q3c, Q5c, Q6c, Q6m, Q7m, Q7vc, Qal, Qbb, Qbp, Qh, Qhs, Qoah Qoam, Qoas, Qor, Qpa, Qs, Qt, Qsw, Qsc

Formation name abbreviations from Dibblee (2002), Ponti and Burke (1980) and Barrows and others (1985)

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

The strong-motion record selected for the slope stability analysis in the Valyermo Quadrangle was the Southern California Edison (SCE) Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the magnitude and PGA values of the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. 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 are used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and the 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 0.24 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Valyermo Quadrangle.

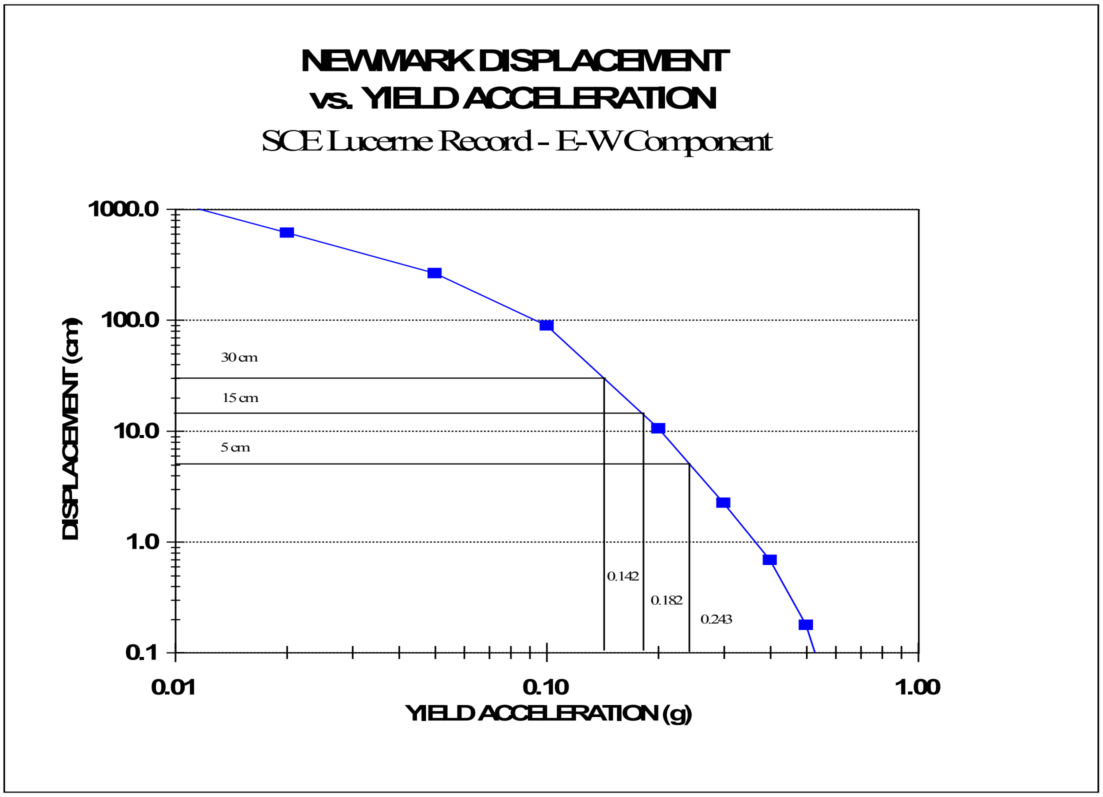

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1992 Landers Earthquake SCE Lucerne Record.

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 follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned.

2. Likewise, if the calculated yield acceleration fell between 0.14g and 0.18g, 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 0.18g and 0.24g, 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 0.24g, 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.

VALYERMO QUADRANGLE HAZARD POTENTIAL MATRIX				
Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (35)	0 to 44%	44 to 50%	50 to 55%	>55%
2 (30)	0 to 32%	32 to 38%	38 to 42%	>42%
3 (16)	0 to 5%	5 to 10%	10 to 15%	>15%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Valyermo 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 3 is included for all slopes steeper than 5 percent. (Note: The only geologic unit included in Geologic Strength Group 5 is Qls, existing landslides. They have been included or excluded from the landslide zones on the basis of the criteria described in the previous section).
2. Geologic Strength Group 2 is included for all slopes steeper than 32 percent.
3. Geologic Strength Group 1 is included for all slopes steeper than 44 percent.

This results in 17 percent of the entire quadrangle and 20 percent of the study area lying within the earthquake-induced landslide hazard zone for the Valyermo Quadrangle.

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I.K. Curtis Services, 1974, Frames 2074-2086 and 2142-2154; black and white; vertical; approximate scale 1:6,000.

I.K. Curtis Services, 1976, Flight IKC-C, Frames 13-27; color; vertical; approximate scale 1:12,000

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Department of Public Works	5
Ritter Ridge Quadrangle	47
Palmdale Quadrangle	19
Littlerock Quadrangle	20
Lancaster West	2
Sleepy Valley	2
Juniper Hills Quadrangle	34
Total Number of Shear Tests	129

SHEAR STRENGTH GROUPS FOR THE VALYERMO 7.5-MINUTE QUADRANGLE		
GROUP 1	**GROUP 2**	**GROUP 3**
ps, hqm,	af	Qls
bgm, hdgn, hqd	Q*, Q**	
gr, gr-m	Tp	
grc,	Tpc, Tps	
gn	Tprc	
cgn	Tpb, Tpv	
m	TQjh,	
ms	TQjhb	
qd		

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

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Valyermo 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 CGS for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.8
Modal Distance:	2.0 to 12 km
PGA:	0.53 to 0.90g

SECTION 3
GROUND SHAKING EVALUATION REPORT

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

By

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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) [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/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 (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.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

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

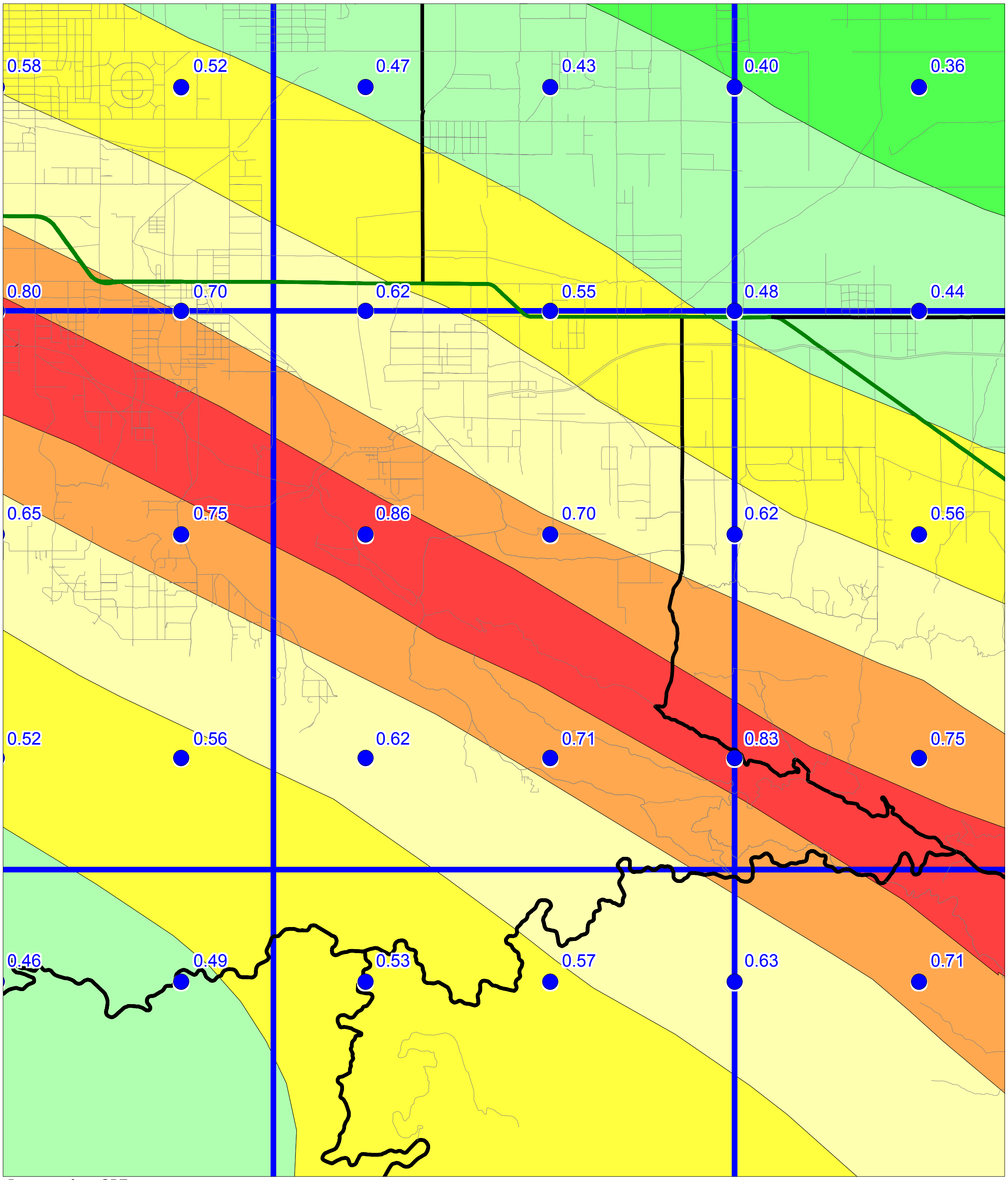
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

VALYERMO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

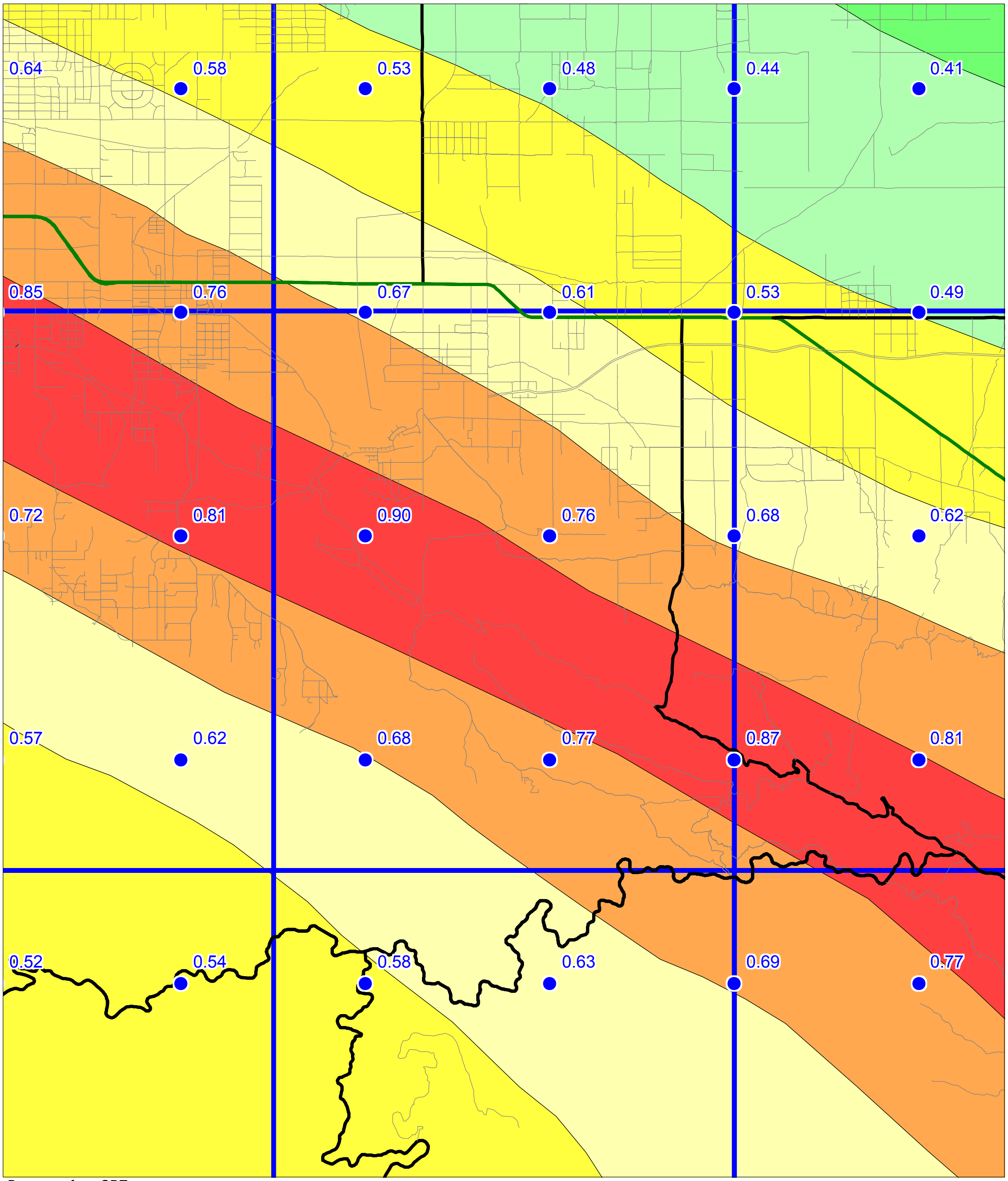
Figure 3.1

VALYERMO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

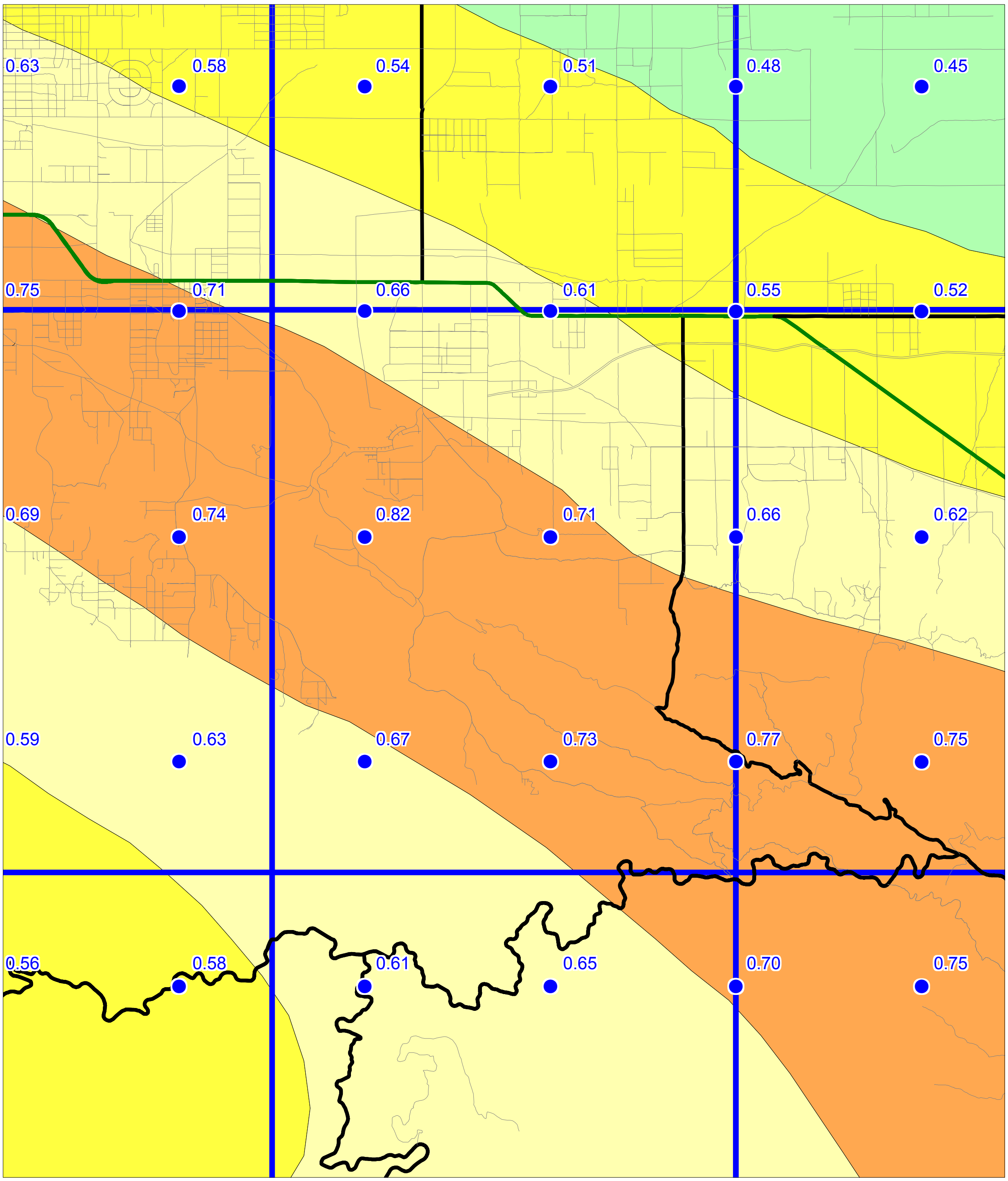
Department of Conservation
California Geological Survey

Figure 3.2

VALYERMO 7.5 MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)
1998

ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3
Miles

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.

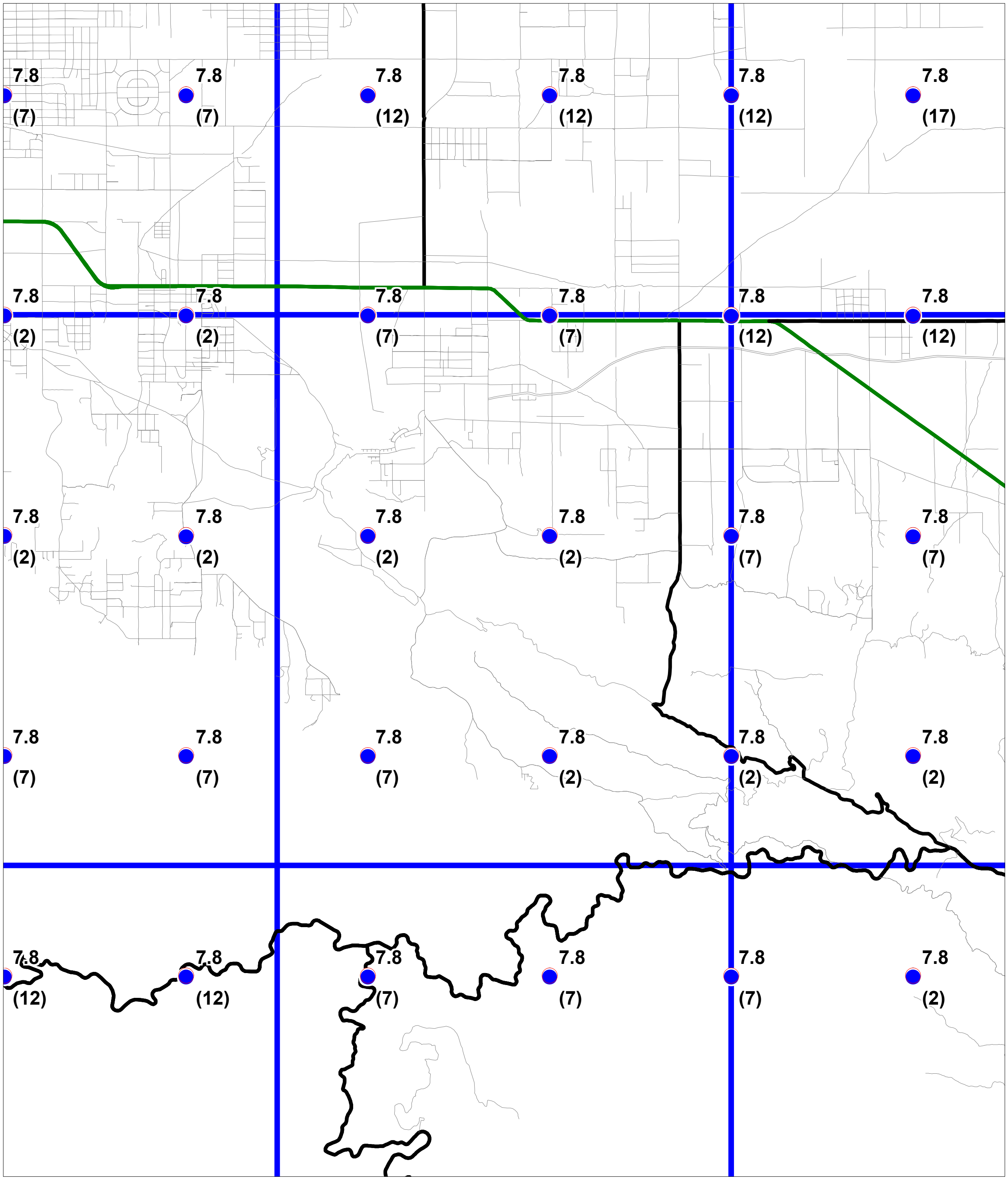
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

VALYERMO 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 from GDT

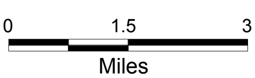


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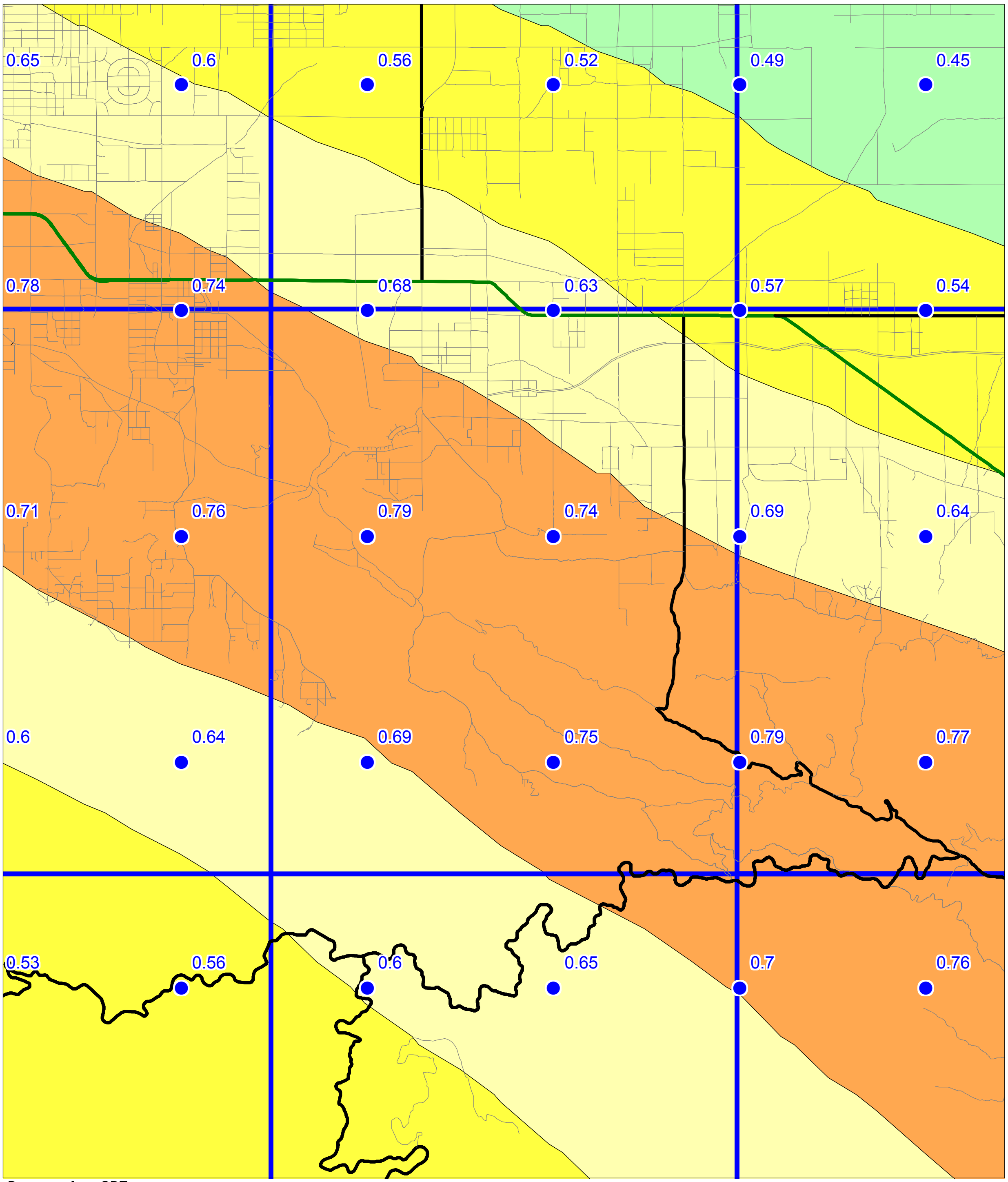
Figure 3.4

VALYERMO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

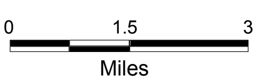
10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT



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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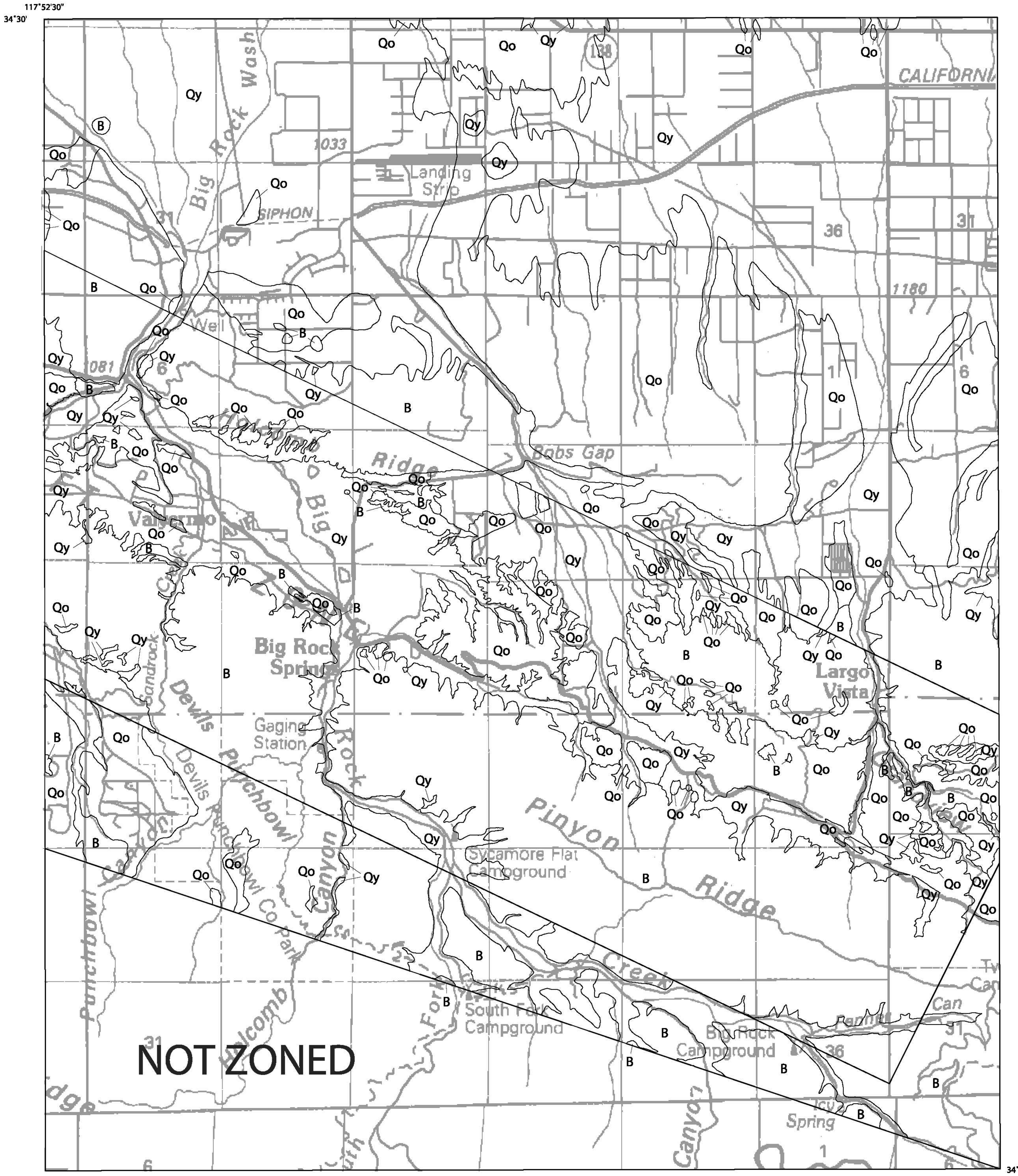


Base map enlarged from U.S.G.S. 30 x 60-minute series

VALYERMO QUADRANGLE

SCALE

N

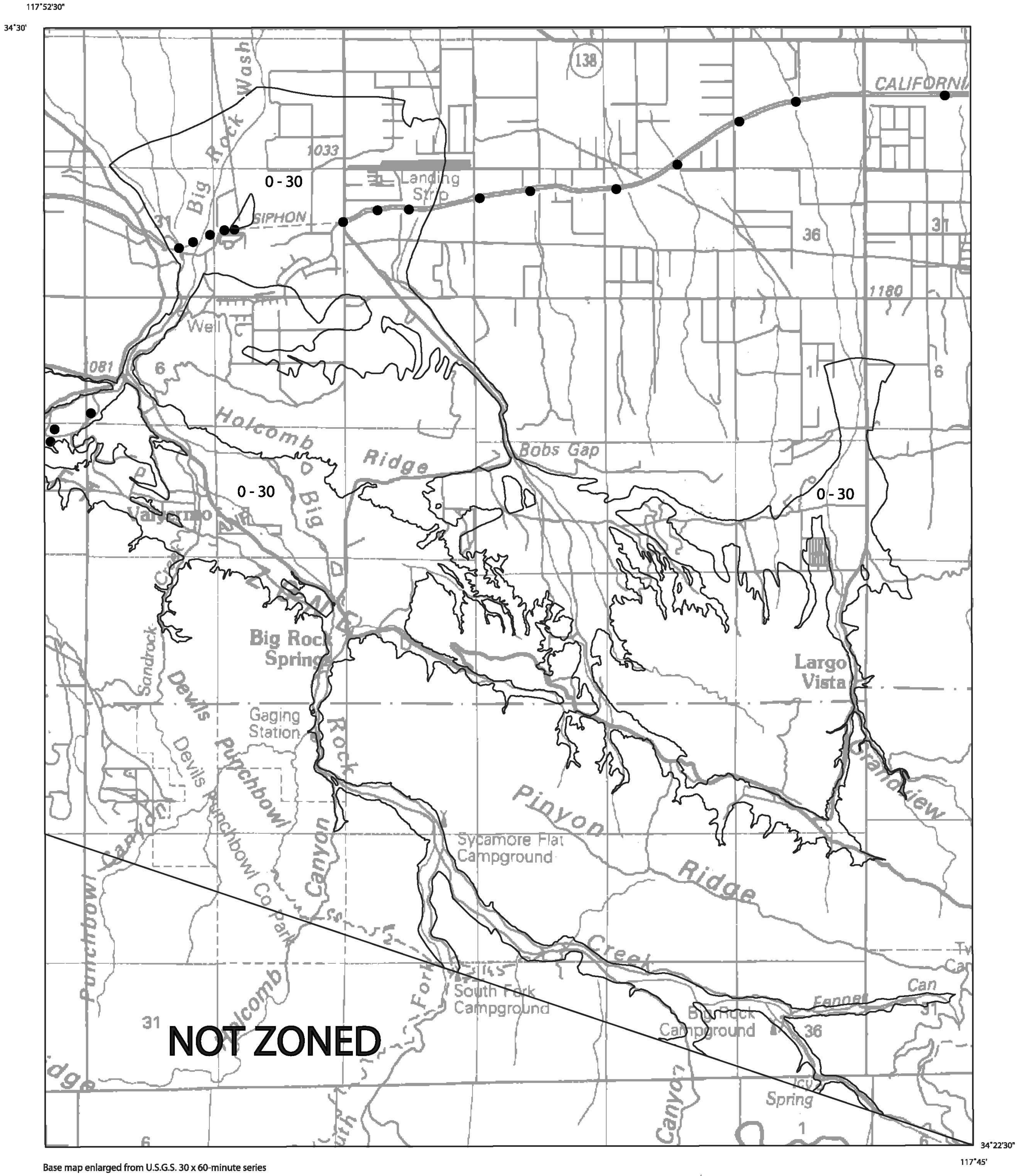
Geologic Contact

Geologic Map Section Boundary

B = Pre-Quaternary bedrock.

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Plate 1.1 Quaternary Geologic Map of the Valyermo 7.5-Minute Quadrangle, California. Northern, central, and southern map sections are modified from Ponti and Burke (1980), Barrows and others (1985), and Dibblee (2002), respectively.



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

VALYERMO QUADRANGLE

SCALE

N

Depth to ground water, in feet

0 - 30

Geotechnical boring site

Plate 1.2 Depth to historically shallowest ground water and locations of boreholes used in this study, Valyermo 7.5-Minute Quadrangle, California.

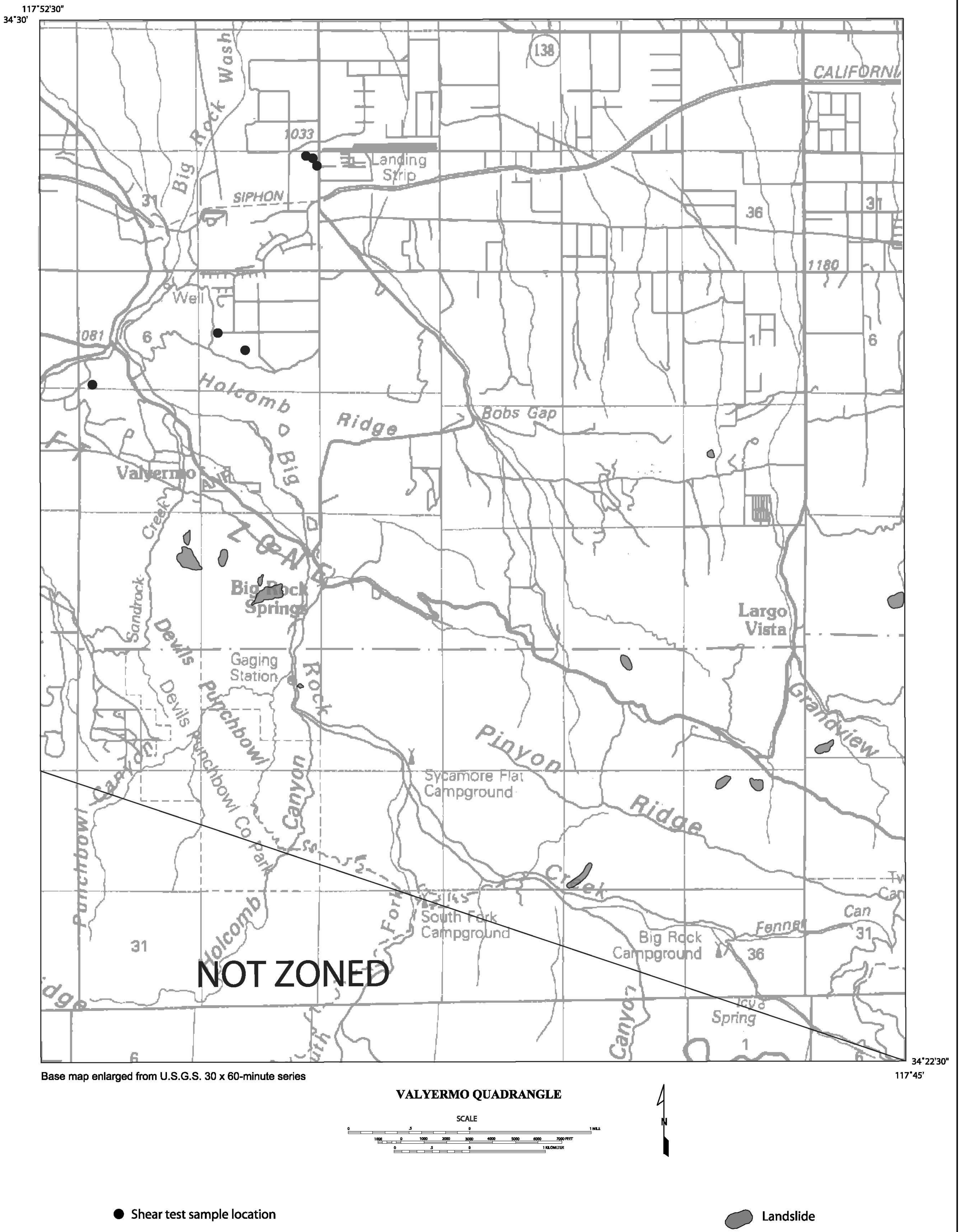


Plate 2.1 Landslide inventory and shear test sample locations, Valyermo 7.5-Minute Quadrangle, California.