OPEN-FILE REPORT 98-07

SEISMIC HAZARD EVALUATION OF THE BURBANK 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

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Division of Mines and Geology

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the 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.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

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

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), 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 Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

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

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

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

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Burbank 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By

Christopher J. Wills

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic 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 (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Burbank 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

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

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

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, 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 and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine 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 potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Burbank Quadrangle covers an area of about 62 square miles in west-central Los Angeles County. The City of Burbank lies completely within the quadrangle, near its center, which is about 9 miles northwest of Los Angeles City Hall. Much of the City of Glendale extends along the entire eastern border of the quadrangle across the Verdugo Mountains. Universal City, which covers about one square mile, also lies entirely within the map area near the southwestern corner. The remainder of the quadrangle is covered by communities that are parts of the City of Los Angeles, including North Hollywood, Toluca Lake, Sun Valley, and Tujunga.

Most of the intensive development within the quadrangle is situated on the San Fernando Valley floor or within the Tujunga Valley in the extreme northeastern corner. Several freeways cross this heavily urbanized region, including the Golden State (I-5), the Ventura (State Highway 134), the Hollywood (State Highway 170) and the Foothill (I-210). The Burbank-Glendale-Pasadena Airport is located within the western part of the quadrangle. South of the Los Angeles River, the easternmost part of the Santa Monica Mountains is included within Griffith Park of the City of Los Angeles, which straddles the southern boundary of the quadrangle. The Verdugo Mountains rise above the cities of Burbank and Glendale and extend cross the northeastern third of the map area.

The San Fernando Valley is an east-trending structural trough within the Transverse Ranges of southern California. The San Gabriel Mountains, and their southern outlier the Verdugo Mountains, which bound the valley on the northeast, are composed of plutonic and metamorphic rocks that are being elevated along thrust faults over the valley from the north. As the mountains have risen and been deformed, the San Fernando Valley has subsided and filled with sediment.

The eastern portion of the valley, including most of the Burbank Quadrangle, has received sediment from Pacoima and Tujunga washes. These washes are associated with large river systems that have their sources in the steep, rugged San Gabriel Mountains, which are comprised of crystalline bedrock. The rivers have deposited a broad alluvial fan composed of sand, silt, and gravel that blankets most of the Burbank Quadrangle. The remainder of the San Fernando Valley is covered by smaller alluvial fans that have been deposited by local streams. Streams from the Verdugo Mountains have deposited alluvial fans composed of sand and silty sand similar to the larger Tujunga fan. Small streams that drain the Santa Monica Mountains are so much smaller than the Tujunga fan that they do not form recognizable deposits beyond the narrow canyons in the Santa Monica Mountains.

GEOLOGIC CONDITIONS

Surface Geology

Late Quaternary geologic units in the San Fernando Valley area were completely re-mapped for this study and a concurrent study by engineering geologist Chris Hitchcock of William Lettis and

Associates. Lettis and Associates received a grant from the National Science Foundation (NSF) to study the activity of the Northridge Hills uplift. As part of the research for this study, Hitchcock mapped Quaternary surficial units by interpreting their geomorphic expression on aerial photographs and topographic maps. The primary source for this work was 1938 aerial photographs taken by the U.S. Department of Agriculture (USDA). His interpretations were checked and extended for this study using 1952 U.S.D.A. aerial photos, 1920's topographic maps and subsurface data. The resulting map (Hitchcock and Wills, 1998) represents a cooperative effort to depict the Quaternary geology of the San Fernando Valley combining surficial geomorphic mapping and information about subsurface soils engineering properties. The portion of this map that covers the Burbank Quadrangle is reproduced as Plate 1.1.

In preparing the Quaternary geologic map for the San Fernando Valley, geologic maps prepared by Tinsley and others (1985), Yerkes (1996), and Dibblee (1991a; 1991b) were referred to. We began with the map of Yerkes (1996) as a digital file in the DMG Geographic Information System. The Quaternary geology shown on the map of Yerkes (1996) was compiled from Tinsley and others (1985). For this study, we did not review or revise the mapping of bedrock units by Yerkes (1996), except at the contacts between bedrock and Quaternary units. Within the Quaternary units, mapping by Hitchcock (and for this study) was used to refine and substantially revise the mapping of Tinsley and others (1985). For this map (Plate 1.1), geologic units were defined based on geomorphic expression of Quaternary units (interpreted from aerial photographs and early-edition topographic maps) and subsurface characteristics of those units (based on borehole data). The nomenclature of the Southern California Areal Mapping Project (SCAMP) (Morton and Kennedy, 1989) was applied to all Quaternary units (Table 1.1).

	Alluvial Fan Deposits	**Alluvial Valley Deposits**	**Age**
Active	Qf- active fan	Qa- active depositional basin	
	Qw- active wash		
Young	Qyf2	Qyt	Holocene?
	Qyf1		
Old	Qof1		Pleistocene?

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

The Quaternary geologic map (Plate 1.1) shows that the part of the San Fernando Valley within the Burbank Quadrangle is largely covered by an alluvial fan that extends from north of the quadrangle to the Los Angeles River. The major sources of the sediment that make up this fan have been the river systems that culminate in Tujunga and Pacoima washes, both of which receive sediment from large regions in the San Gabriel Mountains. These river systems begin in high,

rugged mountains composed of crystalline rocks. Periodic torrential rainfall and associated flooding characterize the drainage regimes of these washes. Sedimentation in the study area has resulted primarily in deposits of sand, silt, and gravel, the composition of which reflects the crystalline rocks in the source areas. The major alluvial fan, here referred to as the Pacoima-Tujunga fan, has its head on the San Fernando and Sunland quadrangles, north of the present study area. The Los Angeles River, which flows from west to east across the southern part of the Burbank Quadrangle, has contributed very little sediment to the basin.

The Pacoima/Tujunga alluvial fan can be subdivided based on relative ages of different surfaces. In the Burbank Quadrangle, young alluvium (Qyf2) and two generations of active wash deposits (historic and pre-historic) can be distinguished on the Pacoima/Tujunga fan (Plate 1.1). These units are dominantly composed of sand and silty sand with some gravel.

Subsurface Geology and Geotechnical Characteristics

The geologic units described above were primarily mapped from their surface expression, especially geomorphology as shown on aerial photos and old topographic maps. The geomorphic mapping was compared with the subsurface properties described in over 250 borehole logs in the study area. Subsurface data used for this study include the database compiled by John Tinsley for previous studies (Tinsley and Fumal, 1985; Tinsley and others, 1985), a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998), and additional data collected for this study. Subsurface data were collected for this study at Caltrans, the California Department of Water Resources, CDMG files of seismic reports for hospital and school sites, the Regional Water Quality Control Board and from Law Crandall, Inc., Leighton and Associates, Inc, and Woodward-Clyde Consultants. In general, the data gathered for geotechnical studies appear to be complete and consistent. Data from environmental geology reports filed with the Water Quality Control Board are well distributed areally and provide reliable information on water levels. Geotechnical data, particularly SPT blow counts, from environmental studies are sometimes less reliable however, due to non-standard equipment and incomplete reporting of procedures. Water-well logs from the Department of Water Resources tend to have very sketchy lithologic descriptions and, surprisingly, unreliable reports of water levels. Apparently, water-well drillers may note the level of "productive water," ignoring shallower perched water or water in less permeable layers.

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

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

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized but give the characteristics of the unit most commonly encountered.

Older alluvium (Qof1)

Older alluvium Qof1 is mapped in a part of the Tujunga Valley based on the mapping of Crook and others (1987), who describe this unit (Qal_3f on their map) as unconsolidated fine to medium sand and gravel. No subsurface data was gathered for this unit, which lies in an area of relatively deep ground water near the drainage divide between the Tujunga Wash and Verdugo Wash.

Younger alluvium (Qyf2, Qf, Qw)

Within an alluvial fan, the different generations of younger alluvium can be distinguished by their geomorphic relationships. In the subsurface, it is not possible to distinguish among the generations on an alluvial fan. There may simply be too little difference in age among these units, which probably range from mid-Holocene to historic, for any differences in density or cementation to have formed.

Younger alluvium of the Pacoima/Tujunga fan consists of sand and silty sand with lesser quantities of silt and gravel. In the younger fan deposits and the modern wash, a braided channel pattern is apparent on pre-development aerial photographs. Braided channels lead to lenticular bedding which usually cannot be correlated between wells. Most sand and silty sand layers are loose to medium dense (SPT field N values typically range between 5 and 15), but very loose sands with SPT blow counts as low as 1 were recorded in some boreholes. The sand becomes denser with depth, with typical SPT field N values that range from 15 to 30 below 20 feet.

Young alluvial fans from the Verdugo Mountains

The fans of many small streams originating in the Verdugo Mountains have merged to form a continuous alluvial apron on the northeast side of the San Fernando Valley. Generally, these small fans have their apices at the mountain front and extend to the Pacoima-Tujunga fan on the southwest. These fans are composed of sand and silty sand. Generally the near surface deposits have loose to medium dense consistency.

Young alluvium of the Santa Monica Mountains

Alluvium from streams originating in the Santa Monica Mountains is found in the stream valleys. The Pacoima-Tujunga fan from the opposite side of the valley is so much larger that it has overwhelmed any alluvial fans from the Santa Monica Mountains.

Artificial fill (af)

Artificial fill on the Burbank Quadrangle consists of engineered fill for freeways and waste landfills. The freeway fills are shown on the map of Yerkes (1996) and were not modified. The

waste landfills occupy old gravel pits on the northwestern part of the quadrangle. The boundaries of these landfills were remapped, based on maps from the Upper Los Angeles River Watermaster (Blevins, 1995). Because the engineered fills are too thin to affect the liquefaction hazard and the waste landfills are in an area of deep ground water, no effort was made of determine their subsurface characteristics.

GROUND-WATER CONDITIONS

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

The Report of Referee shows that ground water reached its highest levels in 1944, before excessive pumping caused drawdowns throughout the basin. Management of the ground-water resources led to stabilizing of ground-water elevations in the 1960's and, in some cases, rise of ground-water elevations in the 1970's and 1980's to levels approaching those of 1944. Wells monitored by the Upper Los Angeles River Watermaster (Blevins, 1995) show that in most of the eastern San Fernando Valley, water levels have not recovered to the levels of the 1940's. In the southeastern part of the Burbank Quadrangle, however, water levels are up to 10 feet higher than the 1940’s levels.

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

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

In general, the final ground-water depth map shows shallow ground water along the Los Angeles River in the southern portion of the San Fernando Valley. This area was recognized as an area of shallow ground water in the Report of Referee (1962).

The 1944 ground-water depths were checked against the water levels measured in boreholes compiled for this study. Measured ground-water levels from the 1970's, 1980's and early 1990's tend to be 10 to 20 feet deeper than the 1944 water level, but show the same pattern of shallow ground water near the Los Angeles River and deeper ground water to the north. In the Glendale and Burbank areas, water levels recorded in the Los Angeles River Watermaster's report (Blevins, 1944) are up to 10 feet higher than the 1944 levels. Water levels shown on borehole logs collected for this study also show that ground water has risen up to 10 feet above the 1944 levels. The final map of depth to ground water (Plate 1.2) reflects the 1944 water levels over most of the quadrangle with an adjustment in the Burbank and Glendale areas to reflect this recent rise in ground water.

Ground water is also relatively shallow in all canyons in the Santa Monica Mountains where records were examined. In general, it appears that relatively shallow and impermeable bedrock underlying the canyon alluvium helps to maintain a shallow water table.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of 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 susceptibility units, and introduced the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to evaluate liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study is similar to Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (1993), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes will be that level of peak ground acceleration (PGA) with a 10% probability of

exceedance in a 50-year period. The earthquake magnitude is the magnitude that contributes most to that acceleration.

For the Burbank Quadrangle, peak accelerations of 0.51 g to 0.74 g, resulting from earthquakes of magnitude 6.4 to 7.0 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense. Cohesive soils are generally not considered susceptible to liquefaction.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground water hydrology. Soil property and soil condition factors such as type, age texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related in terms of the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.2.

Old alluvium (Qof1)

Old alluvium on the Burbank Quadrangle consists of unit Qof1 in the Tujunga Valley. This material is described from surface mapping as unconsolidated fine to medium sand and gravel, but no subsurface data were gathered for this unit. Because of low ground water, liquefaction susceptibility of this unit is thought to be low.

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

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

Artifical fill (af)

Artificial fill on the Burbank Quadrangle consists of engineered fill for freeways and waste landfills. The engineered fill is generally too thin to affect liquefaction susceptibility. The waste landfills are located in the northwestern part of the quadrangle, an area of deep ground water. They have low liquefaction susceptibility due to the deep ground water.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Qw, stream channels	Sandy, silty sand	Loose-moderately dense	High
Qf, active alluvial fans	Silty sand, sand, minor clay	Loose-moderately dense	High
Qyf2, younger alluvial fans	Silty sand, sand, minor clay	Loose-moderately dense	High
Qyf1, young alluvial fan	Silty sand, sand, minor clay	Loose-moderately dense	High
Qof1, older alluvial fan	Sand & gravel	Dense	Low

Table 1.2. General geotechnical characteristics and liquefaction susceptibility of younger Quaternary units.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses, expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Of the nearly 270 borehole logs compiled for this study, only 77 had blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc.) required for an ideal Seed Simplified Analysis. For

boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values, or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

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

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

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic 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 (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Burbank Quadrangle is summarized below.

Areas of Past Liquefaction

In the Burbank Quadrangle, no areas of documented historic liquefaction are known. Areas showing evidence of paleoseismic liquefaction have not been reported.

Artificial Fills

In the Burbank Quadrangle, two kinds of artificial fill are large enough to show at the scale of mapping, engineered fill for freeways, and waste landfills. The engineered fills are generally too thin to have an impact on liquefaction hazard and so were not investigated. Areas of waste landfill were remapped based on the report of the Upper Los Angeles River Watermaster (Blevins, 1995) but no attempt was made to determine their engineering properties because all are in areas of deep ground water.

Areas with Existing Geotechnical Data

Younger alluvial deposits (Qyf1, Qyf2, Qyt Qw) of the main Pacoima/Tujunga fan have generally high liquefaction susceptibility. Ground water becomes deeper to the north, however, so the northern portions of these units have not had recorded ground water within 40 feet of the surface. All younger alluvium where ground water has been less than 40 feet from the surface are included in a liquefaction zone.

Areas without Existing Geotechnical Data

Old alluvium on the Burbank Quadrangle consists of sand and silty sand of unit Qof1. This material is described from surface mapping as unconsolidated fine to medium sand and gravel, but no subsurface data were gathered for this unit. Because of relatively deep ground water, this unit was not included in a liquefaction hazard zone.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Burbank 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, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Burbank 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity 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, which includes the Burbank Quadrangle.

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 primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, 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. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. 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 Burbank Quadrangle, for more information on the delineation of Liquefaction Zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Burbank Quadrangle covers an area of about 62 square miles in west-central Los Angeles County. The City of Burbank lies completely within the quadrangle, near its center, which is about 9 miles northwest of Los Angeles City Hall. Much of the City of Glendale extends along the entire eastern border of the quadrangle across the Verdugo Mountains. Universal City, which covers about one square mile, also lies entirely within the map area near the southwestern corner. The remainder of the quadrangle is covered by communities that are parts of the City of Los Angeles, including North Hollywood, Toluca Lake, Sun Valley, and Tujunga.

Most of the intensive development within the quadrangle is situated on the San Fernando Valley floor or within the Tujunga Valley in the extreme northeastern corner. Hillside residential development began after World War II and continues at the present time with several mass-grading projects. Several freeways cross this heavily urbanized region, including the Golden State (I-5), the Ventura (State Highway 134), the Hollywood (State Highway 170) and the Foothill (I-210). The Burbank-Glendale-Pasadena Airport is located within the western part of the quadrangle. South of the Los Angeles River, the easternmost part of the Santa Monica Mountains is included within Griffith Park of the City of Los Angeles, which straddles the southern boundary of the quadrangle. The Verdugo Mountains rise above the cities of Burbank and Glendale and extend cross the northeastern third of the map area.

The San Fernando Valley is an east-trending structural trough within the Transverse Ranges of southern California. The San Gabriel Mountains, and their southern outlier the Verdugo Mountains, which bound the valley on the northeast, are composed of plutonic and metamorphic rocks that are being elevated along thrust faults over the valley from the north. As the mountains have risen and been deformed, the San Fernando Valley has subsided and filled with sediment.

The eastern portion of the valley, including most of the Burbank Quadrangle, has received sediment from Pacoima and Tujunga washes. These washes are associated with large river systems that have their sources in the steep, rugged San Gabriel Mountains, which are comprised of crystalline bedrock. The rivers have deposited a broad alluvial fan composed of sand, silt, and gravel that blankets most of the Burbank Quadrangle. The remainder of the San Fernando Valley is covered by smaller alluvial fans that have been deposited by local streams. Streams from the Verdugo Mountains have deposited alluvial fans composed of sand and silty sand similar to the larger Tujunga fan. Small streams that drain the Santa Monica Mountains are so much smaller than the Tujunga fan that they do not form recognizable deposits beyond the narrow canyons in the Santa Monica Mountains.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

A recently compiled U.S. Geological Survey (USGS) geologic map was obtained in digital form (Yerkes, 1996) for the Burbank Quadrangle. This map was compared with other geologic maps of the area by Weber and others (1980), Dibblee (1991a; 1991b) and Crook and others (1987). This mapping was briefly field checked, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

The San Gabriel Mountains in the northeast corner of the quadrangle, and their southern outlier the Verdugo Mountains, are blocks of plutonic and metamorphic rocks that are being thrust over the San Fernando Valley from the north. The crystalline bedrock forms very steep slopes, which are prone to severe erosion and debris flows. Erosion of these actively rising mountain ranges supplies the sediment that has filled the San Fernando Valley.

Bedrock geology in the crystalline bedrock of the Verdugo and San Gabriel Mountains shown by Yerkes (1996) was simplified to just one unit called dgn (diorite and gneiss). Though other workers differentiate areas underlain by Mesozoic diorite from gneiss in the area, no significant differences in material strength or landslide density were found between these units. The simplified bedrock geology of Yerkes (1996) was used for our study.

Cretaceous granitic rocks (gr) are also exposed in the eastern Santa Monica Mountains, where they are overlain unconformably by shallow-marine clastic sedimentary rocks and volcanics of the middle Miocene Topanga Group and deep-marine biogenic and clastic rocks of the upper Miocene Modelo Formation. The Topanga Group consists of interbedded conglomerate, massive sandstone, concretionary shale and siltstone, and basalt flows (Ttc, Tts, and Tb). The Modelo Formation is composed of interbedded clay shale, siltstone, and sandstone (Tm).

Quaternary deposits cover the floor and margins of the San Fernando Valley and extend southward up into the canyons in the mountains. These units were re-mapped for liquefaction hazards zoning (see Section 1 above). They generally consist of younger alluvial-fan deposits of Holocene age (Qf, Qw, Qyf1, and Qyf2). Landslides (Qls) are found throughout bedrock areas of the Burbank Quadrangle, although they occur primarily in the crystalline bedrock terrain. Modern man-made (artificial) fills (af) were also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Burbank Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked on the basis of their overall shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear strength data for the rock units identified on the geologic map were obtained from the City of Los Angeles, Department of Public Works (see

Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above source were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies, if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. No shear tests were available for Qao, Qay1, Qf, Qof1, Tb, and Ttc (fine grained) and these geologic units were added to existing groups on the basis of lithologic and stratigraphic similarities.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see "Structural Geology") and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

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

Structural Geology

Accompanying the digital geologic map (Yerkes, 1996) were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used this digital structural geologic information and additional data from Dibblee (1991a; 1991b) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Burbank Quadrangle was prepared (Treiman, unpublished) by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. Aerial photos taken by the U.S. Department of Agriculture (1952 and 1953) were the primary source for landslide interpretation. Also consulted during the mapping process were previous maps and reports that contain geologic and landslide data (Dibblee, 1991a, 1991b; Harp and Jibson, 1995; Hoots, 1930; Los Angeles Dept. of Public Works, 1963; and Weber and others, 1979). The

BURBANK QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	**Number of Tests**	**Mean/Median Phi**	**Mean/Median Group Phi (deg)**	**Group Mean/Median C (psf)**	**No Data: Similar Lithology**	**Phi Values Used in Stability Analysis**
GROUP 1	gr Ttc(fbc) dgn	10 24 17	37.3/37 36.2/36.5 34.1/34	35.7/36	576/550	Tb	35.7
GROUP 2	Qw Tm(fbc) Tts(fbc) Qyf1,2	42 25 46 44	32.7/33 32/34 31/32 29.8/31	31.3/32	321/250	Qao Qay1 Qf Qof1	31.3
GROUP 3	Tts(abc)	13	27.6/28.4	27.6/28.4	527/600	Ttc(abc)	27.6
GROUP 4	Tm(abc)	5	23.1/23	23.1/23	431/400		23.1
GROUP 5	Qls	—	—	—	—	—	15

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

Table 2.1. Summary of the shear strength statistics for the Burbank Quadrangle.

SHEAR STRENGTH GROUPS FOR THE BURBANK QUADRANGLE				
Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
dgn gr Tb Ttc(fbc)	af afc Qao Qay1 Qf Qof1 Qw Qyf1,2 Tm(fbc) Tts(fbc)	Ttc(abc) Tts(abc)	Tm(abc)	Qls

Table 2.2. Summary of the shear strength groups for the Burbank Quadrangle.

completed hand-drawn landslide map was scanned, and digitized by the Southern California Areal Mapping Project (SCAMP) at U.C. Riverside. A landslide database was attributed with information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). All landslides on the digital geologic map (Yerkes, 1996) were verified or re-mapped during preparation of the inventory map. To keep the landslide inventory of consistent quality, all landslides originally depicted on the digitized geologic map were deleted, and only those included in the DMG inventory were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Burbank Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.5 to 7.0
Modal Distance:	3.8 to 7.5 km
PGA:	0.53 to 0.77 g

The strong-motion record selected was the Channel 3 (north horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.69 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the

basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Burbank Quadrangle.

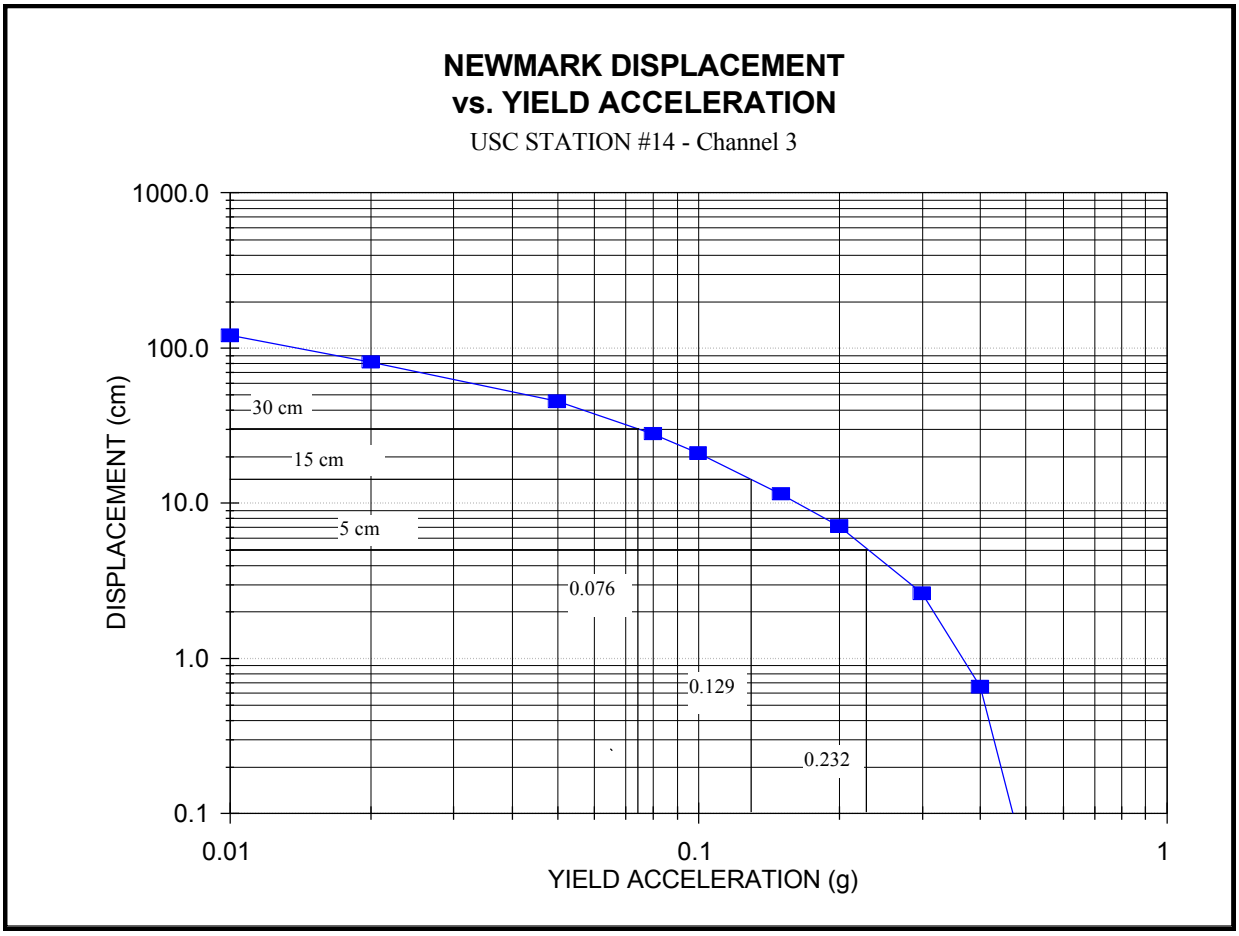

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Burbank Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. A program that adds a pixel to the edges

of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

To update the terrain data to reflect areas that have recently undergone large-scale grading, graded areas in the hilly portions of the Burbank Quadrangle, essentially the Verdugo Mountains, were identified. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and processed by Calgis, Inc. (GeoSAR Consortium, 1995; 1996). The terrain data were also smoothed and filtered prior to analysis. Plate 2.1 shows those areas where the topography is updated to 1994 grading conditions.

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

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 acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) hazard potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) 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.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

BURBANK QUADRANGLE HAZARD POTENTIAL MATRIX											
		SLOPE CATEGORY (% SLOPE)									
Geologic Material Group	Mean Phi	I 0-14	II 14-19	III 19-28	IV 28-30	V 30-36	VI 36-44	VII 44-53	VIII 53-58	IX 58-65	X >65
1	35.7	VL	VL	VL	VL	VL	VL	L	L	M	M
2	31.3	VL	VL	VL	VL	VL	L	M	H	H	H
3	27.6	VL	VL	VL	L	L	M	H	H	H	H
4	23.1	VL	VL	L	L	M	H	H	H	H	H
5	15	L	M	H	H	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Burbank Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker

than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

No earthquake-triggered landslides had been identified in the Burbank Quadrangle prior to the Northridge earthquake. The Northridge earthquake caused a number of relatively small, shallow slope failures in the Burbank Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 8.4 acres of land in the quadrangle. Of the area covered by these Northridge earthquake landslides, 89% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 5 is always included in the zone (mapped landslides); strength group 4 is included for all slope gradients greater than 19%; strength group 3 above 28%; strength group 2 above 36%; and strength group 1, the strongest rock types, were zoned for slope gradients above 44%. This results in roughly 22% of the land in the quadrangle lying within the hazard zone.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Geologic material strength data were collected at the City of Los Angeles, Department of Building and Safety, with the assistance of Nicky Girmay. Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Scott Shepherd and Barbara Wanish for their GIS operations support. Assistance in the application of the radar DEM was provided by Rick Wilson and Tim McCrink.

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APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety	267

SECTION 3
GROUND SHAKING EVALUATION REPORT

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

By

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

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle

and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

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

EARTHQUAKE HAZARD MODEL

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

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

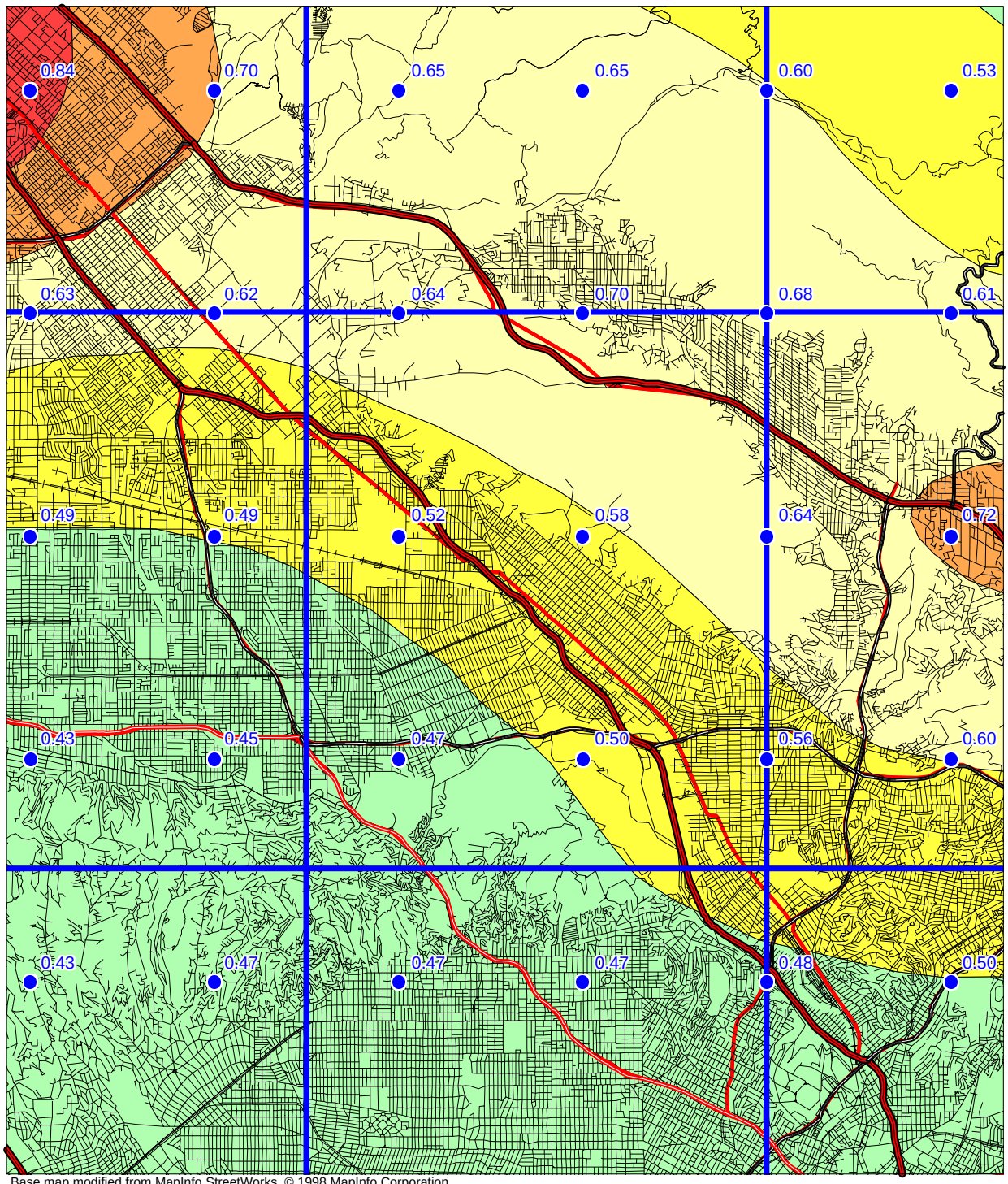
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

BURBANK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

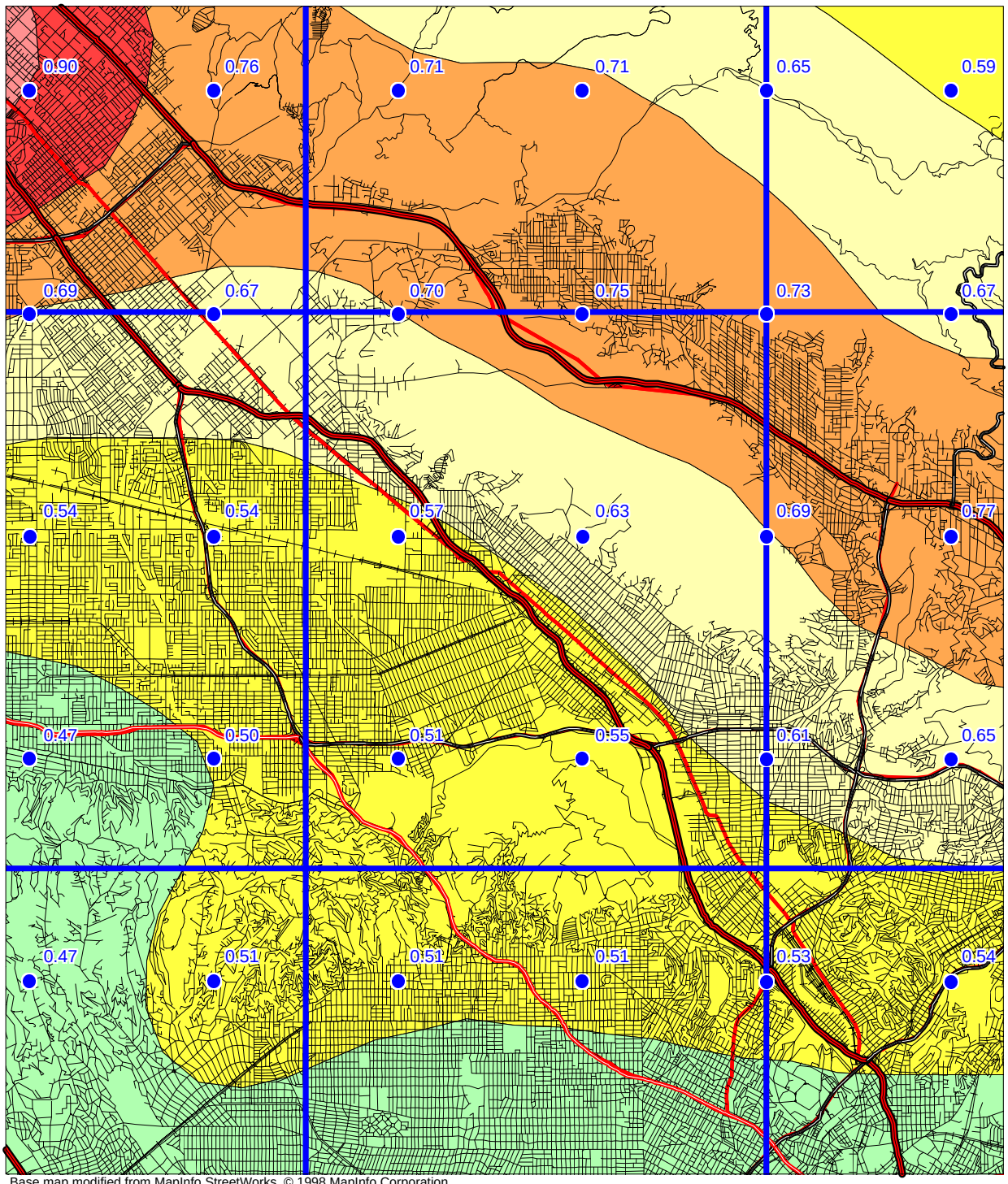
Figure 3.1

BURBANK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

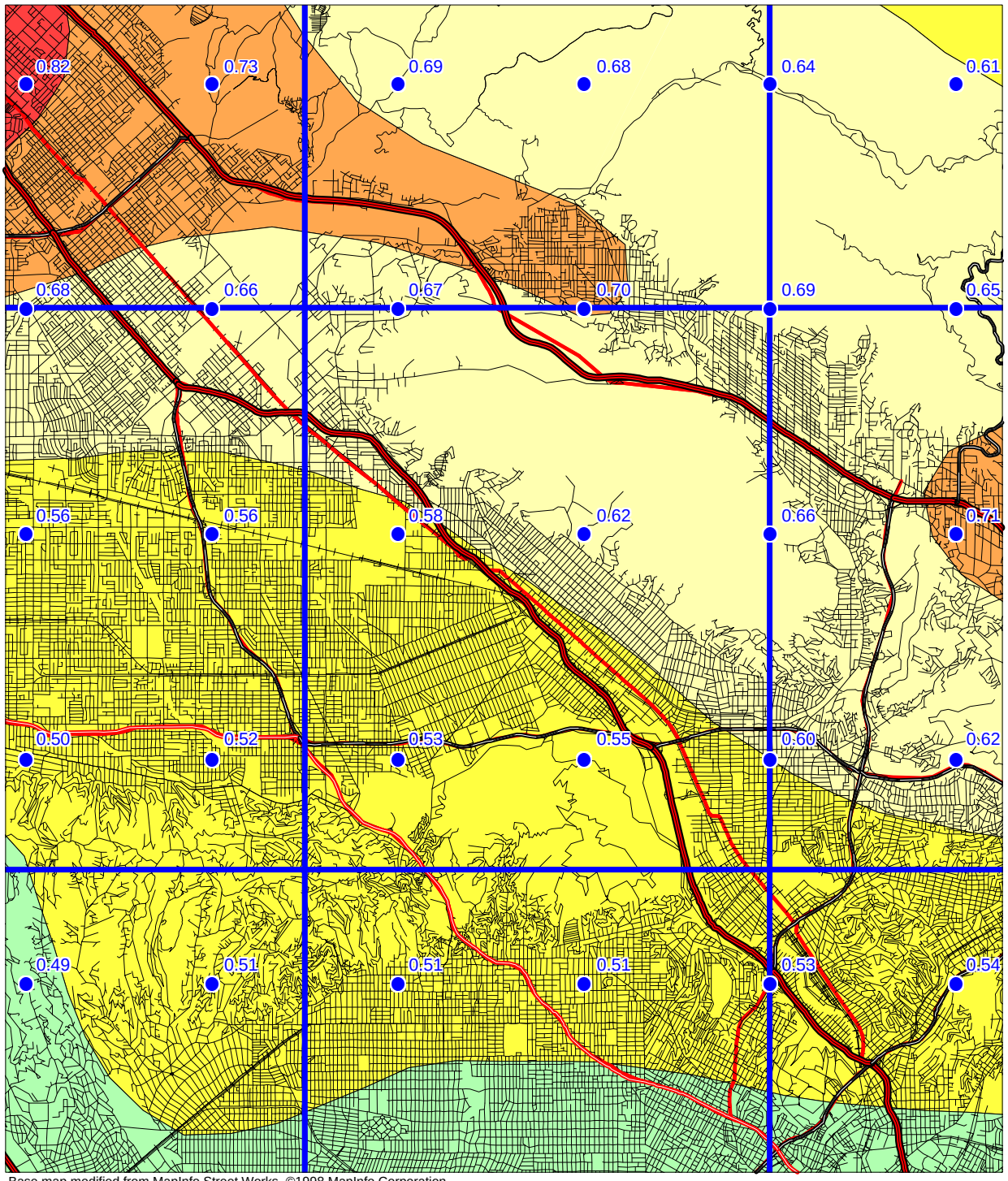
Figure 3.2

BURBANK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

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

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.

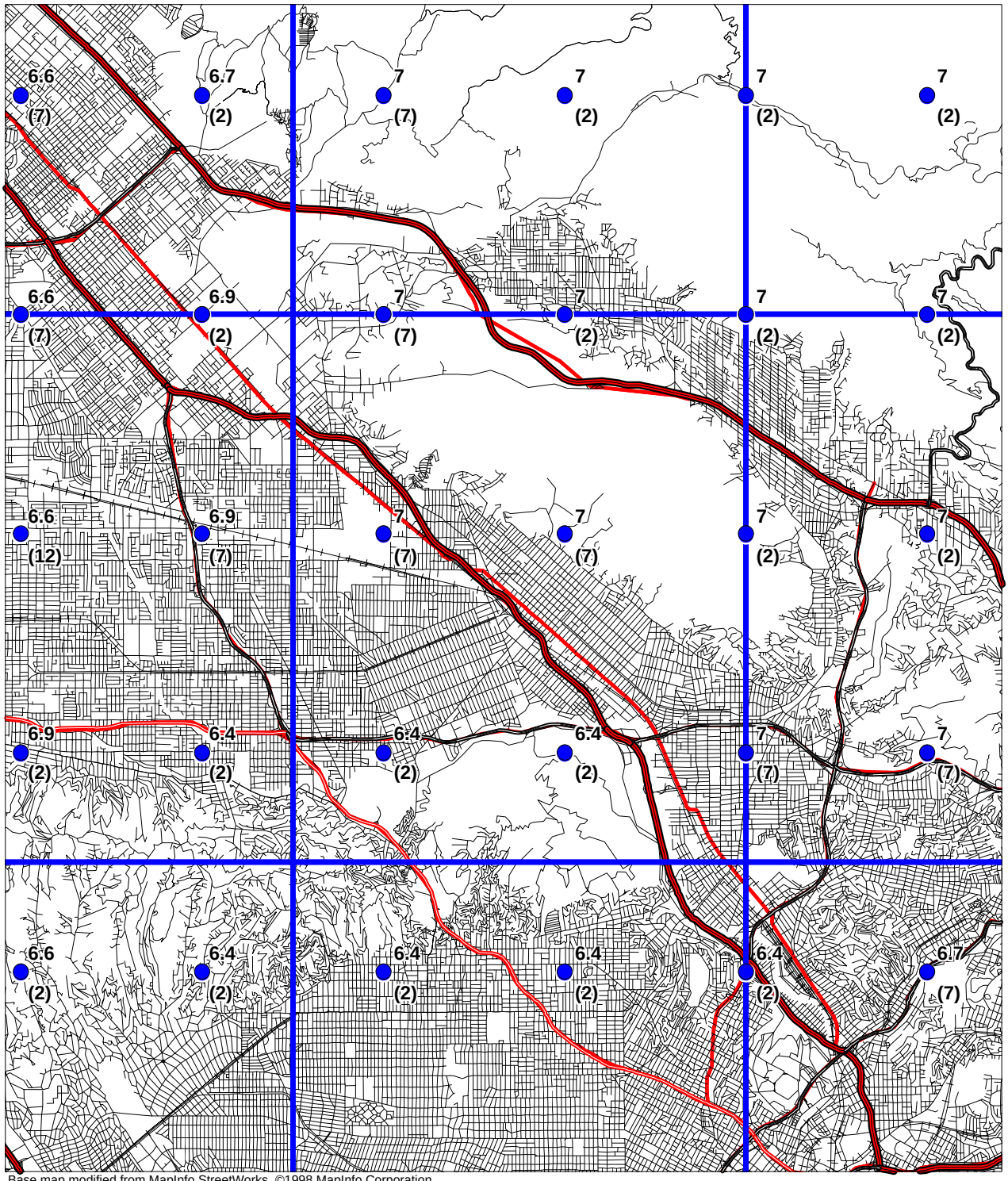
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We

BURBANK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

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



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

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

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been 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 (California State Mining and Geology Board, 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

Plate 1.1 Quaternary Geologic Map of the Burbank Quadrangle.

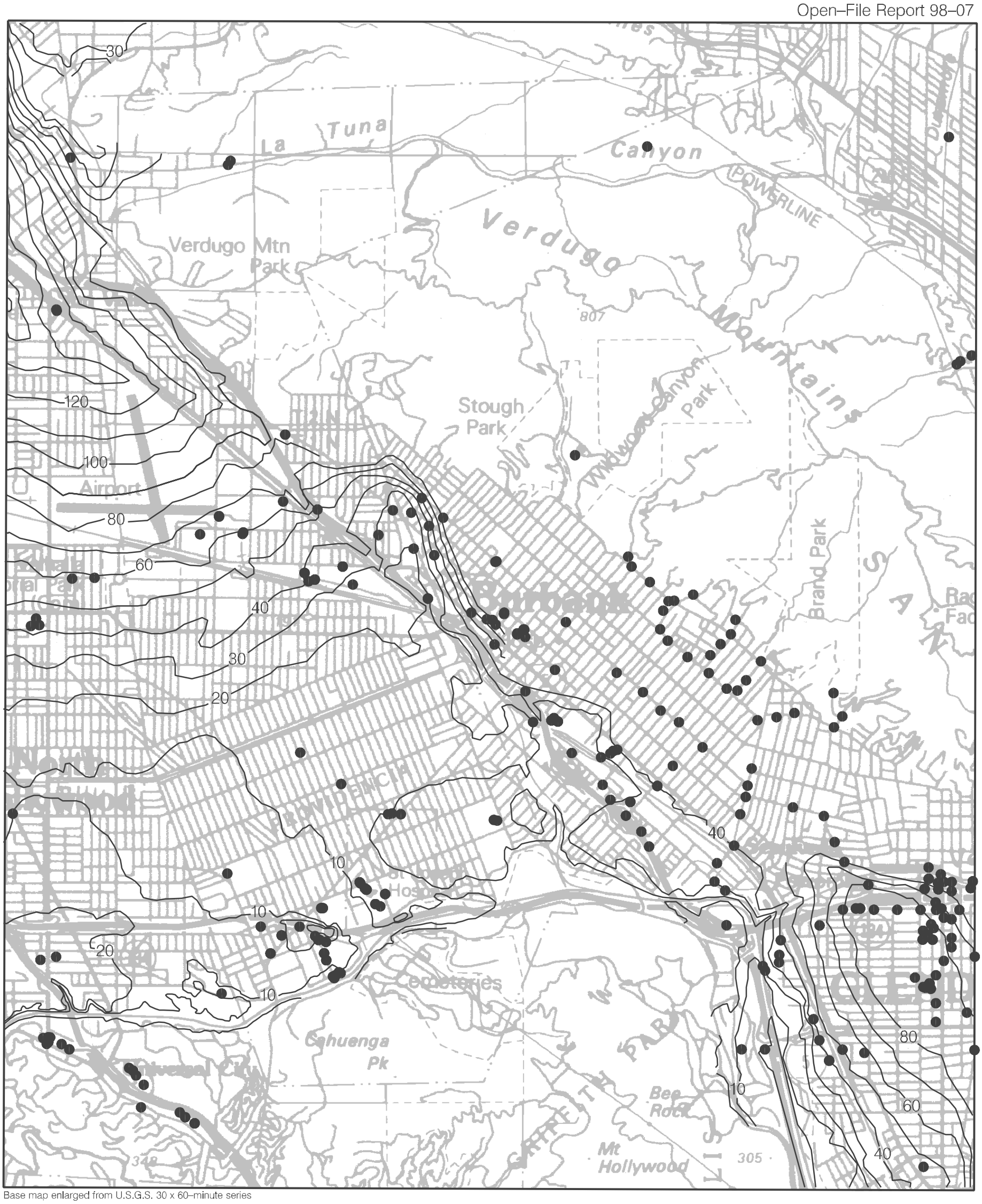
See Geologic Conditions section in report for descriptions of the units.

B = Pre–Quaternary bedrock.

res = reservoir.

ONE MILE

SCALE



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

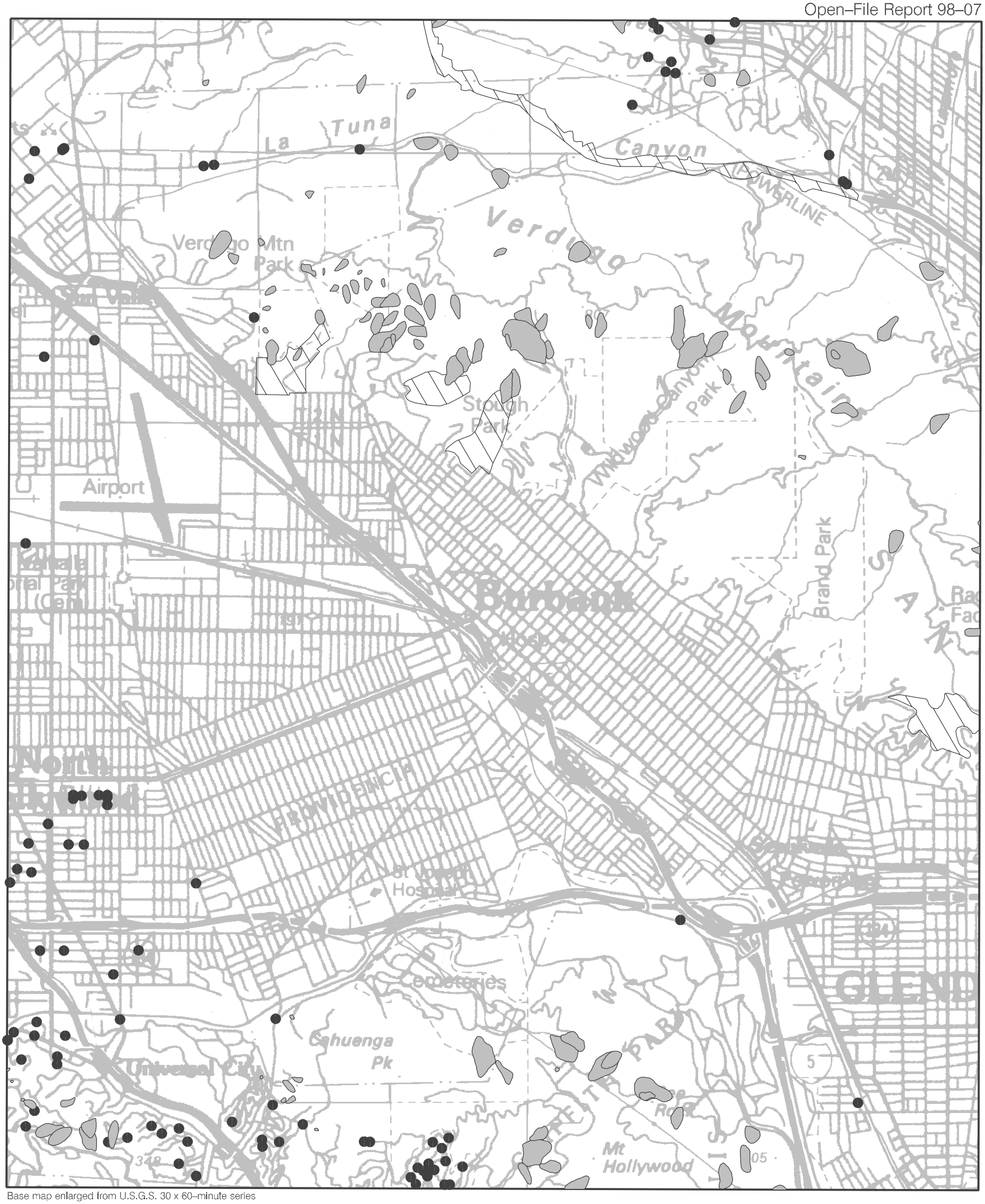
Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Burbank Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE



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

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Burbank Quadrangle.

● shear test sample location landslide areas of significant grading

ONE MILE

SCALE