SEISMIC HAZARD ZONE REPORT 018

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

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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EXECUTIVE SUMMARY

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

The Mint Canyon Quadrangle contains parts of the City of Santa Clarita, including the communities of Newhall and Canyon Country (Solemint Junction), which lies about 27 miles north-northwest of the Los Angeles Civic Center. The remainder of the land within the quadrangle is unincorporated county land, Angeles National Forest or a small part of Placerita Canyon State Park. The Antelope Valley Freeway (State Highway 14) is the primary access to the area. Soledad Canyon Road and Sierra Highway provide additional access. The Santa Clara River flows westward across the center of the quadrangle. Much of the quadrangle is irregular, mountainous, brush-covered terrain cut by numerous canyons, including Sand, Mint, Tick, Bouquet, Texas, Vasquez, and Plum canyons. Placerita Canyon lies close to the southern boundary of the quadrangle. Residential and commercial development, primarily of the canyon-bottom lands, has replaced agricultural and grazing land uses within the area in recent decades. The rest of the area is sparsely occupied, although agricultural activities, small ranches, oil fields, parkland, and National Forest lands are scattered across the quadrangle.

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

In the Mint Canyon Quadrangle the liquefaction zone coincides with the bottoms of the canyons where the water table is close to the surface in sandy materials. The combination of dissected hilly terrain and weak rocks, especially the Mint Canyon Formation, has produced widespread and abundant landslides. These conditions contribute to an earthquake-induced landslide zone that covers about 28 percent of the Mint Canyon Quadrangle, including National Forest land.

How to view or obtain the map

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

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

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

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

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997; also available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf).

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

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

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

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

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By
Wayne D. Haydon

California Department of Conservation
Division of Mines and Geology

PURPOSE

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

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Mint Canyon 7.5-minute Quadrangle. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on DMG's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

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

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

METHODS SUMMARY

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

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

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

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

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

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

SCOPE AND LIMITATIONS

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

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

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

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Mint Canyon Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. Parts of the City of Santa Clarita, including the communities of Newhall and Canyon Country that lie primarily west of the Antelope Valley Freeway (State Highway 14), cover the central and western portion of the quadrangle. The city also extends to an area that straddles Sand Canyon Road, south of the freeway. Canyon Country (Solemint Junction), near the center of the quadrangle, lies about 27 miles north-northwest of the Los Angeles Civic Center. The remainder of the land within the quadrangle is either comprised of unincorporated county land or lies within the Angeles National Forest, except for a small part of Placerita Canyon State Park that lies along the southern boundary. The primary access to the area is via the Antelope Valley Freeway (State Highway 14), which crosses the quadrangle from the southwestern corner to the eastern boundary. East of Solemint Junction, which is located near the freeway crossing of the Santa Clara River, the freeway follows the course of the river, which flows across the center of the quadrangle. West of Solemint Junction, Soledad Canyon Road provides access from Saugus to the west. Sierra Highway, which follows Mint Canyon, crosses the entire quadrangle from southwest to northeast.

The topography of the quadrangle is dominated by irregular, badland to mountainous, brush-covered terrain. Numerous canyons dissect the mountains. Some of the larger canyons, such as Sand, Mint, and Tick canyons, are tributary to the Santa Clara River. Bouquet Canyon, which itself has tributaries including Texas, Vasquez, and Plum canyons, exits the quadrangle in the central part of the western boundary and joins the Santa Clara River in the Newhall Quadrangle. Placerita Canyon lies close to the southern boundary of the quadrangle.

Residential and commercial development, primarily of the lower-lying canyon-bottom lands, has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale. The remainder of the area is largely unoccupied, although agricultural activities, small ranches, oil fields, parkland, and National Forest lands are scattered across the quadrangle.

GEOLOGY

Structural and Depositional Setting

The Mint Canyon Quadrangle lies within the Transverse Ranges geomorphic province of southern California, which is characterized by a complex series of mountain ranges and valleys with dominant east-west trends. Within the Mint Canyon Quadrangle, the Ventura and Soledad depositional basins are juxtaposed along the San Gabriel Fault, a major structural boundary feature that crosses the southwest quarter of the quadrangle. Rocks that accumulated in the Ventura Basin are exposed southwest of the San Gabriel Fault and rocks that accumulated in the Soledad Basin are exposed northeast of the fault. Pre-Cenozoic igneous and metamorphic rocks are exposed along the northern, southern, and southeastern margins of the quadrangle. Most of the rocks exposed within the quadrangle, however, consist of a thick section of fluvial and lacustrine beds that comprise the middle to late Miocene Mint Canyon Formation. North of the San Gabriel Fault these Soledad Basin rocks are overlain, locally, in the western part of the quadrangle by marine strata of the Castaic Formation. Near the eastern boundary of the quadrangle the Mint Canyon Formation was deposited upon older sedimentary rocks belonging to the Tick Canyon and Vasquez formations (Saul and Wootton, 1983).

Nonmarine, Plio-Pleistocene arkosic sandstone, siltstone, and conglomerate beds of the Saugus Formation and Pleistocene, locally coarsely conglomeratic, Pacoima Formation are widespread west of Mint Canyon and south of the San Gabriel Fault. Terrace deposits, older colluvial and fan deposits, and younger alluvium and slope wash are also abundant within the map area. Quaternary alluvium is common in the canyon bottoms and valleys of the streams that are tributary to the Santa Clara River.

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. To evaluate the areal and vertical distribution of shallow Quaternary deposits and to provide information on subsurface geologic, lithologic and engineering properties of the units in the Mint Canyon Quadrangle, we used the digital geologic map of Yerkes (1996), who compiled and digitized the large-scale geologic maps of Saul and Wootton (1983) and Saul (1985). Other geologic maps reviewed for this project include: Oakeshott (1958), Winterer and Durham (1962), Weber (1982), and Dibblee (1996). Only the types of geologic units that are generally susceptible to liquefaction were evaluated. Such units include the Quaternary alluvial and young fluvial sedimentary (flatland) deposits and artificial fill. The geologic maps from Saul and Wootton (1983) and Saul (1985), which were compiled and digitized by Yerkes (1996), provided the most detailed mapping of the Quaternary fluvial and alluvial flatland sedimentary deposits. However, the mapping of the Quaternary deposits was inconsistent across the map and was not considered detailed or accurate enough to use for evaluating the liquefaction susceptibility of the different Quaternary units exposed in the Mint Canyon Quadrangle. Therefore, a reconnaissance geologic map for use in this project was prepared that focused upon differentiating Quaternary fluvial and alluvial flatland sedimentary deposits. The mapping was based on the evaluation of flatland geomorphology, aerial photograph interpretation, examination of soil survey maps (Woodruff and others, 1966), review of subsurface borehole logs and field reconnaissance. The reconnaissance geologic map differs from the map of Yerkes (1996), in that much of the bedrock-alluvium contact was remapped in greater detail and some of the unit designations were reassigned, based upon a reevaluation of the age of each unit or its geomorphic expression. The geologic units were also grouped more consistently.

Quaternary fluvial and alluvial flatland sedimentary deposits were mapped in the main and tributary valleys and canyons of the Santa Clara River Valley, Haskell Canyon, Bouquet Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon, Mint Canyon, Baker Canyon, Tick Canyon, Oak Spring Canyon, Sand Canyon, Iron Canyon and Placerita Canyon. Most of the soil series developed on the deposits, interpreted in the mapping for this project as late Holocene fluvial and alluvial units, are those generally considered to overlie Holocene geologic units (Tinsley and Fumal, 1985).

Active washes were mapped along the incised channels in the main and tributary canyons and valleys. The most prominent wash in the study area is mapped along the Santa Clara River, where the wash generally occupies the approximate center of the Santa Clara River Valley. The washes are partially filled with sand and gravel deposited as bedload by wet-season stream flow. These washes are incised into the late Holocene fluvial deposits of the valley floors.

Active fluvial deposits were mapped as small, planar, non-incised or slightly incised deposits, generally on the smaller tributary canyon floors. Active fan and alluvial apron deposits were mapped as small- to moderate-size, respectively, convex- (downslope) outward fan-shaped or planar, non-incised or slightly incised deposits emanating from small drainages onto the small- to moderate-size tributary valley floors.

Included with the fans are small areas of colluvium that were not mapped separately for this project. In Yerkes (1996) most of the unnamed smaller canyons that are tributary to the larger named canyons were mapped as colluvium. Active alluvial fans were mapped emanating from some of the smaller tributary canyons in Yerkes (1996) but were identified more frequently emanating from more of the smaller tributary canyons during mapping conducted for this project.

Late Holocene fluvial deposits were mapped along the planar, slightly to moderately incised, gently downstream-sloping floors of all the named main and most of the tributary canyons and valleys. The largest of these deposits was mapped in the unnamed tributary canyons and valleys along: the southern margin of the Santa Clara River Valley at the confluence of the unnamed canyons in the western half of the study area; along the northern margin of the Santa Clara River Valley at the confluence of the unnamed canyons in the eastern half of the study area; along the northern margin of Bouquet Canyon; and along the northern margin of Mint Canyon. In Yerkes (1996), many of the larger named canyons are mapped as flood plain deposits. These include the Santa Clara River Valley, Bouquet Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon and the northern part of Mint Canyon. Most of the alluvial deposits in the unnamed tributary canyons as well as Baker Canyon, Sand Canyon, Iron Canyon, much of Oak Spring Canyon, the southern part of Mint Canyon and Placerita Canyon are shown in the map of Yerkes (1996) as colluvium.

Late Holocene alluvial fans were mapped as the convex-outward fan shaped deposits that slope toward the main trunk stream and valley floor. These deposits form individual fans or coalesce to form alluvial aprons along the margins of the main canyons and valleys and emanate from some of the tributary canyons. These alluvial fans and aprons were identified along the margins of nearly all the named main valleys. The largest deposits are: along the eastern margin of Bouquet Canyon between Vasquez and Plum canyons; along the northern margin of the Santa Clara River Valley at the confluence of Mint Canyon; and the unnamed canyon west of Mint Canyon and Sand Canyon. The alluviated flatlands upslope from the fans in the tributary valleys were mapped as active or late Holocene fluvial deposits.

Where water levels are high, younger Holocene fluvial and alluvial deposits are generally considered to have moderate to high liquefaction susceptibility (Youd and Perkins, 1978).

Terrace deposits (Qt) were mapped on erosional surfaces in the upland areas on the map of Yerkes (1996) and during the detailed mapping for this project.

Older colluvium (Qco) and colluvium (Qc) was mapped as scattered surficial deposits in the upland areas on the map of Yerkes (1996) and during the detailed mapping for this project.

Artificial fill was mapped, both by Yerkes (1996) and during the mapping for this project, in the south and west end of Bouquet Canyon and Plum Canyon, and the south half of Tick Canyon. The fill is generally thin and was placed during the grading for relatively recent, large residential and commercial developments.

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from reports on geotechnical work done in the project area. For this investigation, 119 borehole logs were collected from the files of the Los Angeles County Department of Public Works; California Regional Water Quality Control Board, Los Angeles Region; and private consultants. However, the boreholes are too widely spaced and unevenly distributed to adequately describe the subsurface geology or geotechnical properties of the flatland deposits. All of the moderate to large alluviated canyons contain very few to no boreholes at all. Evaluation of borehole logs and reconnaissance mapping of the younger deposits indicate that the fluvial and alluvial deposits consist primarily of coarse-grained sediments, mostly sand, silty sand and gravel, with interbeds of silt and clay. These deposits are discussed below, grouped into two locales or physiographic environments, based on the relative proportions of the coarser-grained sediment types (sand, silty sand, and gravel) to the finer-grained material (silt and clay).

Data from borehole logs were entered into a DMG geotechnical 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.

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

Santa Clara River Valley, Placerita Canyon and associated larger alluvial canyons

The gently sloping, planar valley floors of the Santa Clara River Valley, Bouquet Canyon, Mint Canyon, Tick Canyon, Oak Spring Canyon, Sand Canyon, and Placerita Canyon are underlain by fluvial sediments deposited by the streams flowing down the valleys. These areas were generally mapped as floodplain (Qfp) in Yerkes (1996), except in Placerita Canyon were these deposits were mapped as colluvium (Qc). These deposits consist primarily of brown, dark brown, gray-brown and green-gray, well graded, fine- to coarse-grained and poorly graded, fine-, fine- to medium- and medium- to coarse-grained sand. Deposits are generally described as gravelly, with a trace of scattered or occasional fine- or fine- to medium-grained gravel and often with pebbles, cobbles and boulders.

The very coarse-grained clasts occur primarily as individuals surrounded by sand and rarely as interbeds. In some places, the sand units are gravel free.

The sand deposits contain interbeds of brown, light brown, yellow-brown and red-brown, fine-, fine- to medium-, medium- to coarse-, fine- to coarse- and coarse-grained silty sand. Gravel contents are generally described as trace, slightly, or some cases, fine- or fine- to medium-grained gravel with some of the silty sands containing occasional pebbles and cobbles and some without gravel. In general, the silty sand interbeds appear to contain a smaller percentage of gravel, pebbles and cobbles, with a larger percentage that do not contain gravel, compared to the more abundant sand units.

Occasionally, thin interbeds were identified of brown, gray-brown, green-brown and dark gray, sandy silt or clay. The sands are generally fine or fine to coarse with none to a trace or little fine gravel.

The sands and silty sands are generally described as loose in the very shallow deposits with the deeper deposits described as medium dense to very dense. Deposits containing gravel, pebbles, or cobbles are typically described as denser then deposits without or with apparently smaller percentages of the very coarse clasts. Along the Santa Clara River Valley, over 58% of the measured or corrected SPT N values are greater than 50 blows, in the very dense range, with 22% of the N values between 31 and 50 blows, in the dense range and about 18% with blow counts between 11 and 30, in the medium dense range. Along Bouquet Canyon, Plum Canyon and Texas Canyon, 25% of the N values exceed 50 blows, in the very dense range, with about 50% in the 11 to 30 blow count range and 25% of the N values are between 31 and 50 blows, in the dense range. In the silt or clay interbeds the N values were less than 8, generally in the medium stiff range. However, as described in the Quantitative Liquefaction Analysis section, the gravel clasts probably cause many of the N values in the sand and silty sand units to be too high.

Dry unit weights in the sands and silty sands along Bouquet Canyon, Plum Canyon, and Texas Canyon, were between 101 and 110 pounds per cubic foot (pcf) for over 50% of the soil samples with over 30% in the 111 to >120 pcf range and 13% in the 91 to 95 pcf range. Moisture contents were generally below 15% but varied up to about 20 %. No dry unit weight values were identified for the Santa Clara River Valley.

Based on the age and depositional environment of this deposit, the generally gravelly sand and silty sand are interpreted as being loose to medium dense.

Alluvial fans flanking the larger alluvial canyons and smaller alluvial canyons

The gently sloping, small- to moderate-size convex-outward (downslope) fan-shaped or planar surfaces emanating from small-to moderate-size drainages onto the small and the main tributary valley floors are underlain by active alluvial fan and alluvial-apron deposits. These deposits were typically mapped as colluvium (Qc) or, locally, as fans (Qf) in Yerkes (1996). These deposits consist primarily of brown, light brown, gray-brown, and rarely yellow-brown and red-brown, silty sand. The sand is fine to medium, fine to coarse, or fine grained. Gravel contents are generally described as trace, few, slightly, or gravelly, with much of the silty sands containing pebbles and cobbles and some without gravel. In general, the silty sand deposits appear to have a similar gravel content to the silty sand interbeds in the larger alluvial valleys.

The silty sand deposits contain interbeds of brown, light brown, gray-brown, yellow-brown and red-brown, fine-, fine- to medium-, medium- to coarse- and fine- to coarse-grained sand. Gravel contents are generally described as gravelly, slightly gravelly or trace with much of the sands containing pebbles and cobbles, rarely without gravel. In general, the sand interbeds appear to have a similar gravel content to the sand deposits in the larger alluvial valleys.

Thin interbeds of dark brown or brown, sandy silt were identified occasionally. The sand sizes, however, were not specified and the interbeds apparently contain no gravel.

The sands and silty sands are variously described as firm, soft to firm, moderately loose, and moderately firm, as well as loose, in the very shallow deposits. In the deeper deposits these sands are described as medium dense to dense and, rarely, very dense. In the tributary canyons to the Santa Clara River Valley, Plum Canyon, Bouquet Canyon, and Texas Canyon about 27% of the measured or corrected SPT N values are greater than 50 blows, in the very dense range, with 29% of the N values between 31 and 50 blows, in the dense range and about 41% with blow counts between 11 and 30, in the medium dense range. However, as described in the Quantitative Liquefaction Analysis section, the gravel clasts probably cause many of the N values in the sand and silty sand units to be too high. In the tributary canyons to the Santa Clara River Valley at the eastern margin of the study area, to Tick Canyon and throughout the unnamed canyons west of Tick Canyon on the north side of the Santa Clara River Valley, 74% of the N values were between 5 and 20 blows, in the loose to the lower half of the medium dense range, with the remaining 26% fairly evenly spread out between 21 and >50 blows, in the upper half of the medium dense to the very dense range. These N values are in the range expected for deposits of the interpreted age and depositional environment.

Dry unit weights of the silty sands and sands in the tributary canyons to the Santa Clara River Valley, to Plum Canyon, to Bouquet Canyon and to Texas Canyon were between 106 and >120 pcf for 77% of the soil samples with the remaining 23% primarily between 91 and 106 pcf. In the tributary canyons to the Santa Clara River Valley at the eastern margin of the study area, to Tick Canyon and throughout the unnamed canyons west of Tick Canyon on the north side of the Santa Clara River Valley, dry unit weights are generally lower with 95% of the values between 91 and 115 pcf, 5% with values between 116 and >120 pcf. Dry unit weights of the silt interbeds were generally between 91 and 105 pcf, but ranged from about 86 to >120 pcf. Moisture contents of the silty sands, sands and silts were generally below 10% but ranged up to about 25%.

Based on the age and depositional environment of this deposit the generally gravelly silty sand and sand are interpreted as being loose to medium dense.

GROUND-WATER CONDITIONS

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

Ground-water conditions were investigated in the Mint Canyon Quadrangle to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation was based on first-encountered water noted in geotechnical borehole logs acquired from published ground-water investigations (Robson, 1972) that summarized ground-water conditions in the study area for the years 1945 to 1967, annual maps of the ground-water elevation contour in the alluvial valley deposits prepared by the Los Angeles County Department of Public Works, Hydraulic/Water Conservation Division (LACDPW) for the years 1945 through 1995 (LACDPW, 1995), and from the collected geotechnical and environmental borehole logs. The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not utilized.

Depth- to-Ground Water Contour Map Preparation

Interpretation of Robson (1972) and LACDPW (1995) indicates that no one single year's ground-water elevation contour map of the alluvial valley aquifer represents the shallowest recorded ground-water levels for all of the study area. The shallowest recorded ground-water levels in various parts of the study area occurred in different years. A ground-water elevation contour map of the shallowest recorded water levels for the study area was compiled from the LACDPW ground-water contour maps from various years that represented the shallowest ground-water identified in parts of the study area. The regions of the study area and the year of the ground-water elevation contour map used to compile the ground-water map are as follows: in the Santa Clara River Valley, 1969 with the 1,700 foot contour from 1977 and the 1,650 and 1,675 foot contours from 1967; in Bouquet Canyon, 1983, with the 1,625 foot contour from 1975; in Sand Canyon and Oak Spring Canyon, 1983 with the 1,775 and 1,800 foot contour from 1978; in Mint Canyon, 1993 with the 1,775 through 1,925 foot contours from 1995; in Placerita Canyon, 1995. The depth to the shallowest recorded ground-water map is presented on Plate 1.2.

The depth-to-ground water contour map (Plate 1.2) was prepared by comparing the compiled shallowest ground-water elevations with the ground surface elevations. The applicability of this method to accurately depict alluvial ground-water conditions in the study area was evaluated by noting the depth to ground water in boreholes identified in the flatlands. These borehole ground-water depths were compared to the depth to ground water recorded on the LACDPW ground-water contour maps for the year the borehole was drilled. Generally, there was good agreement between the depth to ground water identified in boreholes drilled into the alluvium and the depth to ground water recorded in the LACDPW ground-water contour maps for the year the borehole was drilled.

However, some modifications were made to the compiled depth-to-ground water contour map to account for anomalies in the data and to make this map more accurately reflect the most likely ground-water conditions.

The depth to ground water in Sand Canyon is problematic. Inspection of the compiled ground-water contour map indicates that in Sand Canyon the depth to ground water is at a relatively constant depth equal to or less than 25 feet in the northern approximately 1.5 miles of the canyon, in Sections 23 and 26. The depth-to-ground water then descends toward the south to 50 feet within a distance of about 0.75 miles, in the southern portion of Section 35, then becomes shallower toward the south to a depth of 40 feet within less than 0.5 mile. Inspection of the LACDPW ground-water contour maps indicates this is a common ground-water pattern when ground water is shallow in the northern portion of the canyon. However, when ground water is deep in the northern portion of the canyon it also tends to be deep in the southern portion as well.

This deep ground water is peculiar because all the similar canyons in the study area have relatively shallow ground water. This deep measurement to ground-water level may be the result of the monitored well having been partially completed into the Mint Canyon Formation, which underlies the valley alluvium and is likely to have deeper ground water as identified in the Saugus Formation in other portions of the study area (Robson, 1972). The apparent deep ground water may result from the flow of ground water in the well from the alluvium to the underlying Mint Canyon Formation, and the subsequent drawdown in the well.

To investigate whether the apparent deep ground water was the result of wells monitoring bedrock instead of the alluvium, logs of wells in Sand Canyon were obtained from LACDPW and DWR and interpreted. Unfortunately, not all the logs of the wells LACDPW monitors to prepare the yearly ground-water contour maps were available. However, interpretation of the available logs and additional logs from DWR suggests that wells in the northern portion of the canyon monitor the ground water in the alluvium, whereas wells in the southern portion of the canyon monitor ground water primarily in the bedrock or both. This information suggests that the deep ground water recorded on the LACDPW ground-water contour maps for the southern part of Sand Canyon reflects wells in that area measuring the depth to ground water in the bedrock underlying the alluvium. Therefore, the depth to ground water in the liquefaction analysis for Sand Canyon was taken as 20 feet, which is the depth throughout most of the northern portion of the canyon.

Ground-water information was generally lacking in the many small and moderately sized, named and unnamed, alluvial valleys that are tributary to the main valleys of Bouquet Canyon, Mint Canyon, and the Santa Clara River Valley. These tributary canyons merge with the trunk valleys either directly onto the fluvial deposits of the valley floor or onto the alluvial fans emanating from the tributary valleys that flank the larger valleys.

Ground-water data are lacking for the tributary canyons of Bouquet Canyon such as Texas Canyon, Vasquez Canyon, and Plum Canyon, the small tributary canyons to these canyons, as well as the many smaller, unnamed canyons that are tributary to Bouquet Canyon. There are no ground-water data for the tributary canyons of Mint Canyon, including Baker Canyon. Ground-water data are lacking for the tributary canyons of the Santa Clara River Valley, such as the unnamed canyons on the northern and southern margins of the valley, Oak Spring Canyon, and Tick Canyon. Ground-water data are also lacking for the eastern, narrow half of Placerita Canyon, and the large exposures of slopewash to the east of Placerita Canyon. The depth to ground water for the small and moderately sized, unnamed and named tributary canyons was taken as the depth to ground water identified or interpreted at the mouth of the tributary canyon where the canyon merges with either the main valley or the alluvial fans.

Ground-water information is also generally lacking in those portions of Quigley Canyon and Haskell Canyon that lie within this study area. The depth to ground water for these canyons was taken as the northernmost depth-to-ground-water contour identified in each of the valleys to the west of the study area in the Newhall Quadrangle.

Study Area Ground-Water Conditions

The historically shallowest ground-water levels are generally shallow across the study area with extensive areas of very shallow ground water along the larger, named canyons. The compiled ground water and interpreted depth-to-ground water maps are presented in Plate 1.2.

In Bouquet Canyon the depth to ground water is about 25 feet at the western boundary of the study area. The depth to ground water shallows to the north, up the canyon, to between 0 and 10 feet in Section 6, and is interpreted to be about 10 feet up the canyon from the western half of Section 5. In the unnamed canyons tributary and north of Bouquet Canyon in Sections 6 and 31 the depth to ground water is interpreted to be about 0 to 5 feet. In Texas Canyon, Vasquez Canyon, and the unnamed canyons tributary to Bouquet Canyon north of the western half of Section 5, the depth to ground water is interpreted to be about 10 feet. In Plum Canyon, the depth to ground water is interpreted to be less than 25 feet based on the ground-water depth in Bouquet Canyon at the confluence to the two canyons.

In Haskell Canyon and the unnamed tributary canyon the depth to ground water is interpreted to be about 25 feet, based on ground-water conditions identified to the west of the study area in the Newhall Quadrangle.

In Mint Canyon, the depth to ground water ranges from 0 to 20 feet. In the southern half of Mint Canyon and tributary canyons, in Sections 21, 15, 11, and 2, the depth to ground water is between 0 and 10 feet. Ground water along Mint Canyon in Section 1 and the tributary canyons in Sections 2, 35, and 36 deepens to 20 or 25 feet and then shallows up the canyon to 10 feet in Section 31. The depth to ground water is interpreted to be 10 feet for the remainder of Mint Canyon up the canyon in Sections 19 and 30, as well as in Baker Canyon, based on the ground-water depth in the main trunk of Mint Canyon.

Along the Santa Clara River Valley, the depth to ground water ranges from 5 to 25 feet. In the western half of the Santa Clara River Valley, the ground-water depth generally descends from 5 feet along the northern margin of the valley to 15 feet along the southern margin. At the confluence of the moderate-size, unnamed valley along the southern margin of the Santa Clara River Valley in Section 29, the ground-water depth descends to 25 feet and the ground-water depth in the unnamed valley is, therefore, interpreted to be less than 25 feet. The ground-water depth in the unnamed valley along the northern margin of the Santa Clara River Valley in Sections 16 and 17 is interpreted to be 5 feet, whereas the depth to ground water in the unnamed valleys along the southern margin of the Santa Clara River Valley in Sections 19, 20, 23, 27, 28, and 30 is interpreted to be 15 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

Along the western half of the eastern half of the Santa Clara River Valley, the ground-water depth is about 15 feet at the northern and southern valley margins and shallows to about 5 feet in the valley center. At the confluence of the Oak Spring Canyon the ground-water depth descends to 25 feet and the ground-water depth in Oak Spring Canyon is, therefore, interpreted to be less than 25 feet. The ground-water depth in the unnamed valleys along the northern margin of the Santa Clara River Valley in Sections 13 and 14 is interpreted to be 15 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

Along the eastern half of the eastern half of the Santa Clara River Valley, ground water deepens from about 10 feet toward the east to about 25 feet at the eastern boundary of the study area. The ground-water depth in Tick Canyon and the unnamed valley just to the east, along the northern margin of the Santa Clara River Valley, is interpreted to be 10 feet, based on the ground-water depth in the main trunk of the Santa Clara River Valley.

In Sand Canyon the depth to ground water descends from 10 feet at the northern end and along the eastern margin of the canyon towards the west and south to 25 feet in the southeastern corner of Section 26. The remainder of Sand Canyon to the south, as well as Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon are interpreted as having a ground-water depth of less than 25 feet, as described in the Depth-to-Ground Water Contour Map Preparation section of this report.

In Placerita Canyon the ground-water depth is about 20 feet at the western study area boundary and shallows within about 600 feet to the east, upcanyon, to 10 feet. Ground water then deepens to 15 feet upcanyon in the west half of Section 5 and then shallows farther upcanyon to 5 feet in the east half of Section 5. The remainder of the upcanyon, narrow portion of Placerita Canyon is interpreted to have a ground-water depth of 5 feet. The depth to ground water in the tributary canyon in Section 32 is interpreted to be about 10 feet, based on the ground-water depth in the main trunk of Placerita Canyon.

The large exposures of slopewash to the east of Placerita Canyon and small alluvial canyons along the western and eastern study area boundaries are interpreted to have a depth to ground water of about 10 to 20 feet.

In Quigley Canyon, the depth to ground water is interpreted to be less than 40 feet based on ground-water conditions identified to the west of the study area in the Newhall Quadrangle.

PART II

LIQUEFACTION POTENTIAL

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

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

LIQUEFACTION SUSCEPTIBILITY

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

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

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

LIQUEFACTION OPPORTUNITY

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

For the Mint Canyon Quadrangle, peak accelerations of 0.49 to 0.767 g, resulting from earthquakes ranging in magnitude from 6.6 to 7.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

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

Of the 119 geotechnical borehole logs reviewed in this study (Plate 1.2), 32 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

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 Mint Canyon Quadrangle 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 were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

SPT- or CPT-derived density measurements in gravelly soils are unreliable and generally too high because the gravel clasts are too large to fit into the sampler or they bridge the opening of the sampler. The sampler tends to bounce on the clasts in such gravels. Field methods developed to evaluate the liquefaction susceptibility of gravelly soils include:

- using the lowest recorded N value as a representative of the gravelly soil statum

- recording N values for small-depth increments to assess the effect of gravel clasts as a basis for rejection or acceptance of the N value or to infer the N value for the finer-grained matrix of the gravelly deposit

- or to use a large-scale penetration test such as the Becker Hammer Drill, adjust the N values from the Becker test using established relationships to the SPT N values, and then using the adjusted N values in the liquefaction evaluation as for sand.

The quantitative liquefaction analysis performed for this study was complicated by the gravel component of many of the soils. Many of the N values from the gravelly sand strata are suspected of being too high, for the reasons discussed above. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To overcome this problem, the computerized analysis was reinterpreted to account for the gravel content. The log of each borehole was compared to the liquefaction analysis to evaluate if the results of the analysis appeared to have been affected by N values that are too high due to the presence of gravel. Correlations were made between boreholes to identify potentially liquefiable units where the N values appeared to have been affected by gravel content with areas where the N values do not appear to have been affected by the soil gravel content and areas where the boreholes lacked N values, and, accordingly, where no liquefaction analyses were conducted.

In evaluating the liquefaction susceptibility in the Mint Canyon Quadrangle, the results were reviewed of the liquefaction analysis, interpretation of liquefaction susceptibility and zoning decisions made in the similar geologic units exposed in the adjacent Newhall Quadrangle.

From the 32 borehole logs with sufficient information, liquefaction analysis was conducted using the soil parameters collected for 206 of the soil samples. The logs indicate that gravel and/or cobbles were encountered in the strata that about 82% of the samples were collected from. Liquefiable sediments were identified in 38 samples from 14 of the boreholes with about 84% of the these samples being collected from strata containing gravel and /or cobbles. On the basis of the liquefaction analysis and re-analysis of the subsurface soils encountered in the boreholes and the interpreted Quaternary geology, the fluvial and alluvial flatland valley and fan deposits in the Mint Canyon Quadrangle with an historic shallow ground-water depth of less than 40 feet are considered to meet the liquefaction susceptibility zoning criteria under the applied ground motion. All the geologic units either were shown to contain liquefiable sediments by the liquefaction analysis, or were judged to potentially contain liquefiable sediments by correlation with adjacent units or similar units in other portions of the study area or because such units were of similar age and mode of deposition. Sufficient geotechnical data to fully analyze all the units in all portions of the study area were simply not available.

The Quaternary terrace deposits and the older colluvium mapped in the uplands of the study area are considered to be too consolidated and/or to be above the regional ground-water table and therefore do not meet the liquefaction susceptibility zoning criteria under the applied ground motion. Additionally, the small, scattered colluvium deposits were not included in the liquefaction zones because these deposits are above the regional ground-water table and are likely to be saturated only rarely.

Large artificial fills are judged to be recent enough to have been placed using modern grading codes and, therefore, are assumed to have a low liquefaction susceptibility. The liquefaction susceptibility for areas with artificial fill was based on the liquefaction susceptibility of the underlying natural geological unit.

LIQUEFACTION ZONES

Criteria for Zoning

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

1. Areas known to have experienced liquefaction during historical earthquakes

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

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

4. Areas where existing geotechnical data are insufficient

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

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

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

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

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

Areas of Past Liquefaction

Although liquefaction resulting from the San Fernando earthquake of February 9, 1971 was not specifically identified in the quadrangle, the community of Solemint (now called Canyon Country) was described by Evans (1975, p. 143) as the "hardest hit of any community in the area." Solemint is only about 5 miles northwest of the epicenter and most structures in the area are on graded alluvium and, locally, the ground-water table is very shallow.

Following the Northridge earthquake of 1994, although ground ruptures and other liquefaction effects were identified at numerous localities along the Santa Clara River in the Newhall Quadrangle (Stewart and others, 1994), no direct observations of liquefaction-related ground-failure features were made in the Mint Canyon Quadrangle. Along Soledad Canyon Road in Canyon Country there were numerous water pipe breaks both east and west of Sierra Highway (Stewart and others, 1994, figure 4.64). Regardless of the uncertainty as to the direct cause of the breaks, because of the proximity of the breaks to the shallow ground-water saturated sediments along the Santa Clara River all of the localities are included within zones of required investigation for liquefaction.

Artificial Fills

Large artificial fills are judged to be recent enough to have been placed using modern grading codes and, therefore, are assumed to have a low liquefaction susceptibility. The liquefaction susceptibility for areas underlain by artificial fill was based on the liquefaction susceptibility of the underlying natural geological unit. Where fills were mapped across both alluvium and the adjacent bedrock, the liquefaction zone was extended over the alluvium only.

Areas with Sufficient Existing Geotechnical Data

Throughout the study area, the boreholes are grouped into a number of small, isolated and unevenly distributed concentrations, with only about 27% of the boreholes having sufficient information to conduct a liquefaction analysis. No boreholes were identified in most of the flatlands of the alluviated canyons. Therefore, for most of the study area the evaluation of liquefaction susceptibility of the alluvial flatlands is based on the interpreted geologic properties of the deposits rather than direct measurement. This interpretation is based on correlations between liquefaction susceptibility and the age and mode of deposition of the geologic deposits, supported by the results of the liquefaction analysis, interpretation of liquefaction susceptibility and zoning decisions made in the similar geologic units exposed in the adjacent Newhall Quadrangle and the depth to ground water. In summary, the study area does not contain sufficient areal distribution or density of boreholes, nor is the quality of data collected in this investigation from the existing boreholes sufficient to adequately evaluate the liquefaction susceptibility.

Areas with Insufficient Existing Geotechnical Data

Bouquet Canyon and the tributary Texas Canyon, Vasquez Canyon, and Plum Canyon as well as the unnamed small tributary canyons contain several small, isolated and unevenly distributed concentrations of boreholes, although almost all have soil samples with N values and liquefaction analysis. These canyons are underlain by late Holocene fluvial and alluvial geologic units that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The ground-water table has been measured at a depth of generally less than 25 feet at the western margin of the study area in Bouquet Canyon and Plum Canyon, and measured or interpreted to be at a depth of less than 10 feet in most of Bouquet Canyon and in the tributary canyons. Liquefaction analysis of soil samples collected from half of the boreholes identified liquefiable sediments but the boreholes are too widely spaced or too shallow to adequately evaluate the liquefaction susceptibility of these areas. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Bouquet Canyon and the tributary Texas Canyon, Vasquez Canyon, and Plum Canyon, as well as the unnamed small tributary canyons, fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Haskell Canyon and its unnamed tributary canyon no borehole information was obtained. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The interpreted depth to ground water is about 25 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Haskell Canyon and its unnamed tributary canyon fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

Mint Canyon has only a few boreholes in the far southern portion of the canyon and none with N values and liquefaction analysis. Baker Canyon and its tributary canyons contain no boreholes. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The measured depth to ground water in Mint Canyon, Baker Canyon and the tributary canyons is generally less than 10 feet but descends to as much as 25 feet in Sections 1, 2, 35, and 36. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Mint Canyon, Baker Canyon, and its tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

The Santa Clara River Valley, Tick Canyon, Oak Spring Canyon and the moderate-size, unnamed tributary canyons contains several small, isolated and unevenly distributed concentrations of boreholes. However, only a few of these have soil samples with N values and liquefaction analysis. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The ground-water table has been measured at a depth of generally less than 15 feet in the Santa Clara River Valley and is generally interpreted to be at a depth of less than 25 feet in Tick Canyon and Oak Spring Canyon, as well as the unnamed tributary canyons. Less than half of the small number of boreholes with liquefaction analyses encountered liquefiable sediments but the boreholes are too widely spaced or too shallow to adequately evaluate the liquefaction susceptibility of these areas. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the Santa Clara River Valley, Tick Canyon, Oak Spring Canyon, and the moderate-size, unnamed tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Sand Canyon, Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon and the small tributary canyon no boreholes were located. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The interpreted depth to ground water is generally less than 25 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Sand Canyon, Iron Canyon, Gorman Canyon, Coyote Canyon, and Bear Canyon and the small tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Placerita Canyon there are only a few boreholes in the far western portion of the canyon and none with N values and liquefaction analysis. This canyon is underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The depth to ground water in most of the canyon, as well as the tributary canyon in Section 32 is generally measured or interpreted to be less than 10 feet. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Placerita Canyon and its small tributary canyon fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

In Quigley Canyon, the large exposures of slopewash to the east of Placerita Canyon, and the small alluvial canyons along the western and eastern quadrangle boundaries, no boreholes were located. These canyons are underlain by late Holocene fluvial and alluvial geologic deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The depth to ground water in the slopewash and small alluvial canyons is interpreted to be about 10 to 20 feet. In Quigley Canyon, the depth to ground water is interpreted to be less than 40 feet. These areas are underlain by late Holocene fluvial and alluvial deposits that are considered to have a high liquefaction susceptibility based on their age and mode of deposition. The anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Quigley Canyon, the large exposures of slopewash to the east of Placerita Canyon and the small alluvial canyons along the western and eastern quadrangle boundaries fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water, on the overall liquefaction susceptibility of the underlying geologic units and correlation with the liquefaction analysis and zoning decisions made on the adjacent Newhall Quadrangle.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

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

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PURPOSE

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

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

BACKGROUND

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

METHODS SUMMARY

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

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

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

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

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

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

SCOPE AND LIMITATIONS

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

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Mint Canyon 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 Mint Canyon 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 Mint Canyon Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. Parts of the City of Santa Clarita, including the communities of Newhall and Canyon Country that lie primarily west of the Antelope Valley Freeway (State Highway 14), cover the central and western portion of the quadrangle. The city also extends to an area that straddles Sand Canyon Road, south of the freeway. Canyon Country (Solemint Junction), near the center of the quadrangle, lies about 27 miles north-northwest of the Los Angeles Civic Center. The remainder of the land within the quadrangle is either comprised of unincorporated county land or lies within the Angeles National Forest, except for a small part of Placerita Canyon State Park that lies along the southern boundary. The primary access to the area is via the Antelope Valley Freeway (State Highway 14), which crosses the quadrangle from the southwestern corner to the eastern boundary. East of Solemint Junction, which is located near the freeway crossing of the Santa Clara River, the freeway follows the course of the river, which flows across the center of the quadrangle. West of Solemint Junction, Soledad Canyon Road provides access from Saugus to the west. Sierra Highway, which follows Mint Canyon, crosses the entire quadrangle from southwest to northeast.

The topography of the quadrangle is dominated by irregular, mountainous, brush-covered terrain. Numerous canyons dissect the mountains. Some of the larger canyons, such as Sand, Mint, and Tick canyons, are tributary to the Santa Clara River. Bouquet Canyon, which itself has tributaries including Texas, Vasquez, and Plum canyons, exits the quadrangle in the central part of the western boundary and joins the Santa Clara River in the Newhall Quadrangle. Placerita Canyon lies close to the southern boundary of the quadrangle.

Residential and commercial development, primarily of the lower-lying canyon-bottom lands, has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale. The remainder of the area is largely unoccupied, although agricultural activities, small ranches, oil fields, parkland, and National Forest lands are scattered across the quadrangle.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface. Within the Mint Canyon Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours that are based on 1954 and 1956 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Areas that have recently undergone large-scale grading projects since 1960 as a part of residential development were identified on aerial photography flown in the winter and spring of 1994. Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and reprocessed by Calgis, Inc (GeoSAR Consortium, 1995 and 1996). These terrain data were also smoothed prior to analysis. Plate 2.1 shows those areas where the topography is updated to 1994 grading conditions.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map.

The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

For the Mint Canyon Quadrangle, a recently compiled geologic map was obtained from the U.S. Geological Survey (USGS) in digital form (Yerkes, 1996). Yerkes (1996) compiled and digitized the large-scale geologic maps of Saul and Wootton (1983) and Saul (1985). Other geologic maps reviewed for this project include: Oakeshott (1958), Winterer and Durham (1962), Weber (1982), and Dibblee (1996). The digital geologic map was modified to reflect the most recent mapping in the area. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The oldest rocks in the Mint Canyon Quadrangle are a Precambrian gabbro (gb) bordering a large norite-anorthosite basement complex exposed north of the San Gabriel Fault. Assorted pre-Cenozoic gneissic (gn), granitic rocks (gr) and, locally, Pelona Schist (ps) are exposed along the northern boundary of the quadrangle. South of the San Gabriel Fault, the oldest units consist of Placerita Formation metasedimentary rocks (pm) of possible Paleozoic age that have been intruded by Cretaceous granodiorite (gd).

The oldest rocks of the sequence of sedimentary and volcanic rocks that rests upon the basement rocks belong to the Vasquez Formation (Tvz) of Oligocene age, which consists of non-marine red beds and fan deposits of gritty siltstone, sedimentary breccia, claystone, mudstone, and limestone and small amounts of andesitic volcanic rocks (Tvv). Tick Canyon Formation (Ttk) of early Miocene age rests unconformably upon the Vasquez Formation and consists mostly of poorly consolidated conglomeratic sandstone and lesser siltstone of fluvial origin.

The middle to late Miocene Mint Canyon Formation (Tmc) rests unconformably upon the Tick Canyon Formation and is the most widespread Tertiary formation in the quadrangle. The Mint Canyon Formation is predominantly a lacustrine and fluvial sequence that contains several coeval facies. They are, as subdivided by Saul and Wootton (1983): Tmc1- a marginal facies that consists of arkosic sandstone and conglomeratic sandstone, with minor siltstone and silty clay shale; Tmc2 - a bottomset facies containing interbedded claystone, siltstone, silty sandstone, and sandstone and minor conglomerate and limestone; Tmc3 - a deltaic facies that includes arkosic sandstone, sandy conglomerate, interlayered sandy siltstone and claystone, and tuff beds (T). Overlying the Mint Canyon Formation in the northwest corner of the map area and near the San Gabriel Fault is the late Miocene Castaic Formation (Tcs), which consists of shallow marine sandstone and shale distinguishable by the large variety of mollusk species from the late Miocene. Coevally deposited with the Castaic Formation, the late Miocene to early Pliocene Towsley Formation (Tw and Twc), which consists of interbedded marine siltstone, sandstone, and conglomerate, crops out in slivers along the San Gabriel Fault in the southwestern corner of the map area.

The Plio-Pleistocene nonmarine Saugus Formation rests unconformably upon the Towsley Formation. The Saugus Formation consists of a lower unit, the Sunshine Ranch Member (Tsr) of Pliocene age, that has an upper facies (Tsru), mapped only north of the San Gabriel Fault, comprised of sandy siltstone, mudstone, and pebbly and sandy conglomerate and an lower facies (Tsrl) of arkosic sandstone, pebbly sandstone, and conglomerate. The Pleistocene unnamed upper member of the Saugus Formation (Qs) consists of nonmarine arkosic sandstone, sandy conglomerate, sandy siltstone, and claystone. Locally, an upper, coarse-grained, facies (Qsc) of poorly consolidated sandstone and sandy conglomerate and a basal conglomerate (Qsg) are mapped separately. The Pleistocene Pacoima Formation (Qpa), rests unconformably upon the Saugus Formation and consists of a nonmarine unit that ranges from silty sandstone to pebble-boulder conglomerate and is only present south of the San Gabriel Fault.

Quaternary units, such as terrace deposits (Qt), older colluvium (Qco), and fan deposits (Qf) consist of poorly consolidated interbeds of sand, silt, and gravel. Terrace deposits unconformably overlie the Saugus Formation primarily north of the Santa Clara River near the western edge of the map and Mint Canyon Formation on Cruzan Mesa, between Mint Canyon and Bouquet Canyon, and west of Bouquet Canyon.

Younger Quaternary surficial deposits, including units mapped as floodplain deposits (Qfp) and alluvium (Qal) cover the floors of the Santa Clara River Valley, Bouquet Canyon, Haskell Canyon, Texas Canyon, Vasquez Canyon, Plum Canyon, and the northern part of Mint Canyon. The floors of most of the unnamed tributary canyons, as well as Baker Canyon, Sand Canyon, Iron Canyon, much of Oak Spring canyon, the southern part of Mint Canyon, and Placerita Canyon are mapped as colluvium (Qc), which includes sheet wash, rock debris, and overbank deposits that consist of sand, silt, and clay. These deposits extend up into the canyons in the surrounding hills and mountains. Locally, slope wash deposits (Qsw) and pond deposits (Qp) have been mapped. Landslide deposits (Qls) are particularly abundant in the southwestern quarter of the quadrangle where they rest upon Mint Canyon and Saugus formation rocks. Modern man-made fill (af) or artificial cut and fill (afc) are mapped in some areas where development involved massive grading or along the freeway roadbed. A more detailed discussion of the Quaternary deposits in the Mint Canyon Quadrangle can be found in Section 1.

Structural Geology

The northwest-striking San Gabriel Fault, which crosses the southwestern corner of the Mint Canyon Quadrangle, is the dominant structural feature in the area. Other structurally important faults, the Agua Dulce, Soledad, and Pole Canyon faults are either exposed in the basement terrain or inferred to lie beneath the Santa Clara River floodplain. In the western half of the quadrangle, most faults and fold axes, as well as the strike of bedding of the pre-Quaternary rock units, trend subparallel to the strike of the San Gabriel Fault. In the eastern half of the quadrangle, east of Mint Canyon and Sand

Canyon, the pre-Quaternary rock units strike northeast-southwest to north-south and dip to the west. Throughout the quadrangle, dips in the pre-Quaternary units are generally less than 45 degrees. Locally, steeply dipping bedrock (> 45º) exists, primarily south of the Santa Clara River and adjacent to the San Gabriel Fault zone.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Mint Canyon Quadrangle was prepared using interpretation of stereo-paired aerial photographs of the study area (see Air Photos in References) and limited field reconnaissance, Haydon (unpublished). All areas containing landslides identified in the previous work (Saul and Wootton, 1983; Saul, 1985) were reevaluated during the aerial photograph interpretation conducted for this investigation. Some of the landslides identified in the previous work were not included in the landslide inventory because in our reevaluation it was concluded that the feature was not a landslide. Many additional landslides were identified and boundaries of many of the landslides shown in previous work were modified. Additionally, all landslides shown on the digital geologic map (Yerkes, 1996) were verified, remapped or removed during preparation of the inventory map. The completed hand-drawn landslide map was scanned, digitized and the database was attributed with landslide information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). To keep the landslide inventories 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.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Geotechnical and engineering geologic reports contained in Environmental Impact Reports and Hospital Review Project files at DMG are additional sources. Shear-strength data for the rock units identified on the Mint Canyon Quadrangle geologic map were obtained from a variety of sources (see Appendix A). Where no shear strength data was available for very hard rock units, such as granitic rocks in the Mint Canyon Quadrangle, a number was assigned based on field observations and select rock mechanics data sources (Hoek and Bray, 1981; Jumikis, 1983). Where shear strength information was lacking for certain rock units within the Mint Canyon Quadrangle itself, it was collected from adjacent areas. The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

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

Adverse Bedding Conditions

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

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

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

Existing Landslides

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

MINT CANYON QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number of 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, gb, gd	40
GROUP 2	Tmc3(fbc)	52	34/34	35/35	449/300	pm, ps, gn	35
	Tmc1(fbc)	3	35/34			Tvz(fbc), Tvv(fbc)	
	Tcs(fbc)	12	37/37			T(fbc)	
	Tsrl(fbc)	4	35/37			Tw(fbc)	
	Tsru(fbc)	20	36/35			Twc(fbc)	
	Qsc(fbc)	3	37/37			Qsg(fbc)	
GROUP 3	Ttk(fbc)	10	32/32	31/31	404/322		31
	Tmc2(fbc)	23	31/31				
	Qs(fbc)	35	31/30				
GROUP 4	Qs(abc)	17	27/25	28/28	310/249	Qsg(abc),Qsc(abc)	28
	Qt	12	28/30			Qpa, Qco, Qf	
	Qal	88	28/30			Qfp, Qsw	
	af	10	28/27			Qc, afc	
GROUP 5	Ttk(abc)	11	25/24	24/24	629/455	Tvz(abc)	24
	Tmc3(abc)	36	25/26			Tvv(abc)	
	Tmc2(abc)	31	23/23			T(abc)	
	Tmc1(abc)	2	25/25			Tw(abc)	
	Tcs(abc)	9	23/21			Qp	
	Tsrl(abc)	4	22/25				
	Tsru(abc)	24	25/25				
GROUP 6	Qls	16	16/15	16/15	390/253		16

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 Mint Canyon Quadrangle.

SHEAR STRENGTH GROUPS FOR THE MINT CANYON QUADRANGLE					
GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6
gr	pm	Ttk(fbc)	Qs(abc)	Tvz(abc)	Qls
gb	ps	Tmc2(fbc)	Qsg(abc)	Tvv(abc)	
gd	gn	Qs(fbc)	Qsc(abc)	Ttk(abc)	
	Tvz(fbc)		Qpa	T(abc)	
	Tvv(fbc)		Qt	Tmc3(abc)	
	T(fbc)		Qco	Tmc2(abc)	
	Tmc3(fbc)		Qf	Tmc1(abc)	
	Tmc1(fbc)		Qfp	Tcs(abc)	
	Tcs(fbc)		Qsw	Tw(abc)	
	Tw(fbc)		Qc	Tsrl(abc)	
	Twc(fbc)		Qal	Tsru(abc)	
	Tsrl(fbc)		afc	Qp	
	Tsru(fbc)		af		
	Qsg(fbc)				
	Qsc(fbc)				

Table 2.2. Summary of the Shear Strength Groups for the Mint Canyon 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 Mint Canyon Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.6 to 7.8
Modal Distance:	2.5 to 21.9 km
PGA:	0.5 to 0.9 g

The strong-motion record selected for the slope stability analysis in the Mint Canyon Quadrangle was the USC-14 record (Trifunac and others, 1994) from the magnitude 6.7 Northridge earthquake of January 17, 1994. This record had a source to recording site distance of 8.5 km and a peak ground acceleration (PGA) of 0.59g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

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

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

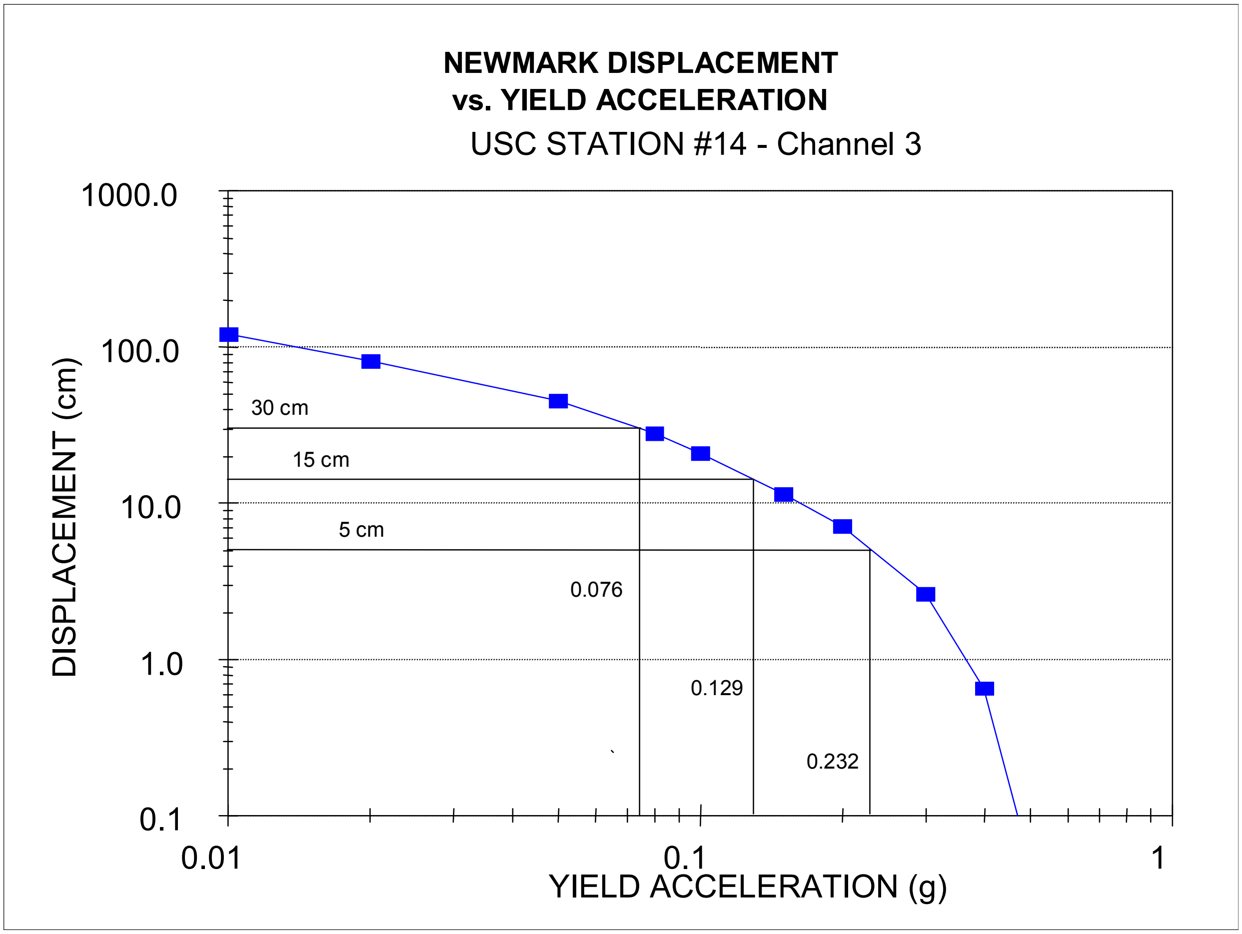

Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

Slope Stability Analysis

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

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

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

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

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

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

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

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

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

MINT CANYON QUADRANGLE HAZARD POTENTIAL MATRIX											
		SLOPE CATEGORY									
Geologic Material Group	**Mean Phi**	**I 0-20%**	**II 21-24%**	**III 25-30%**	**IV 31-35%**	**V 36-40%**	**VI 41-45%**	**VII 46-56%**	**VIII 57-66%**	**IX 67-72%**	**X >72%**
1	40	VL	VL	VL	VL	VL	VL	VL	L	M	H
2	35	VL	VL	VL	VL	VL	VL	L	M	H	H
3	31	VL	VL	VL	VL	L	L	M	H	H	H
4	28	VL	VL	VL	L	L	M	H	H	H	H
5	24	VL	L	L	M	H	H	H	H	H	H
6	16	L	M	H	H	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Mint Canyon Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone. H = High, M = Moderate, L = Low, VL = Very Low.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

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

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

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

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

Existing Landslides

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

The February 9, 1971 San Fernando earthquake likely triggered numerous rockfalls and debris falls in the portion of the San Gabriel Mountains that extends into the southern part of the Mint Canyon Quadrangle (Evans, 1975). These shallow failures were only referred to in general descriptions of the effects of the event and have not been delineated on any maps. The 1994 Northridge earthquake also caused a number of relatively small, shallow slope failures in the Mint Canyon Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 104 acres of land in the quadrangle, which is less than 1/2 of 1 percent of the total area covered by the map. Of the area covered by these Northridge earthquake landslides, 83% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

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

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

1. Geologic Strength Group 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).

2. Geologic Strength Group 4 is included for all slopes steeper than 20 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 30 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 35 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 45 percent.

This results in 28 percent of the land in the Mint Canyon Quadrangle, including National Forest land, lying within the earthquake-induced landslide hazard zone.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Department of Public Works	412
Geotechnical reports from environmental impact documents and DMG staff on file at DMG	10
Total Number of Shear Tests	422

SECTION 3
GROUND SHAKING EVALUATION REPORT

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

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

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

EARTHQUAKE HAZARD MODEL

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

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

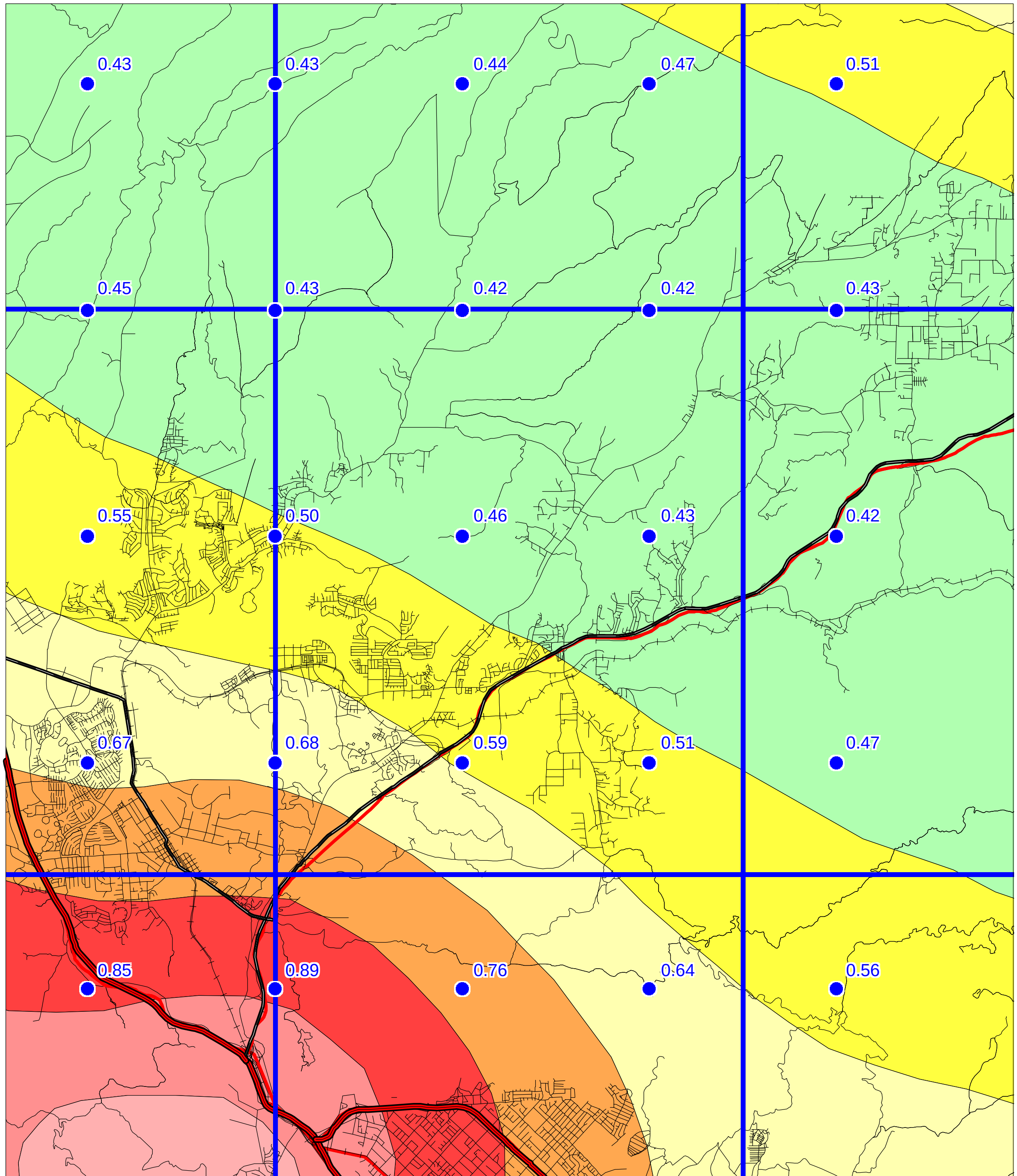
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

MINT CANYON 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

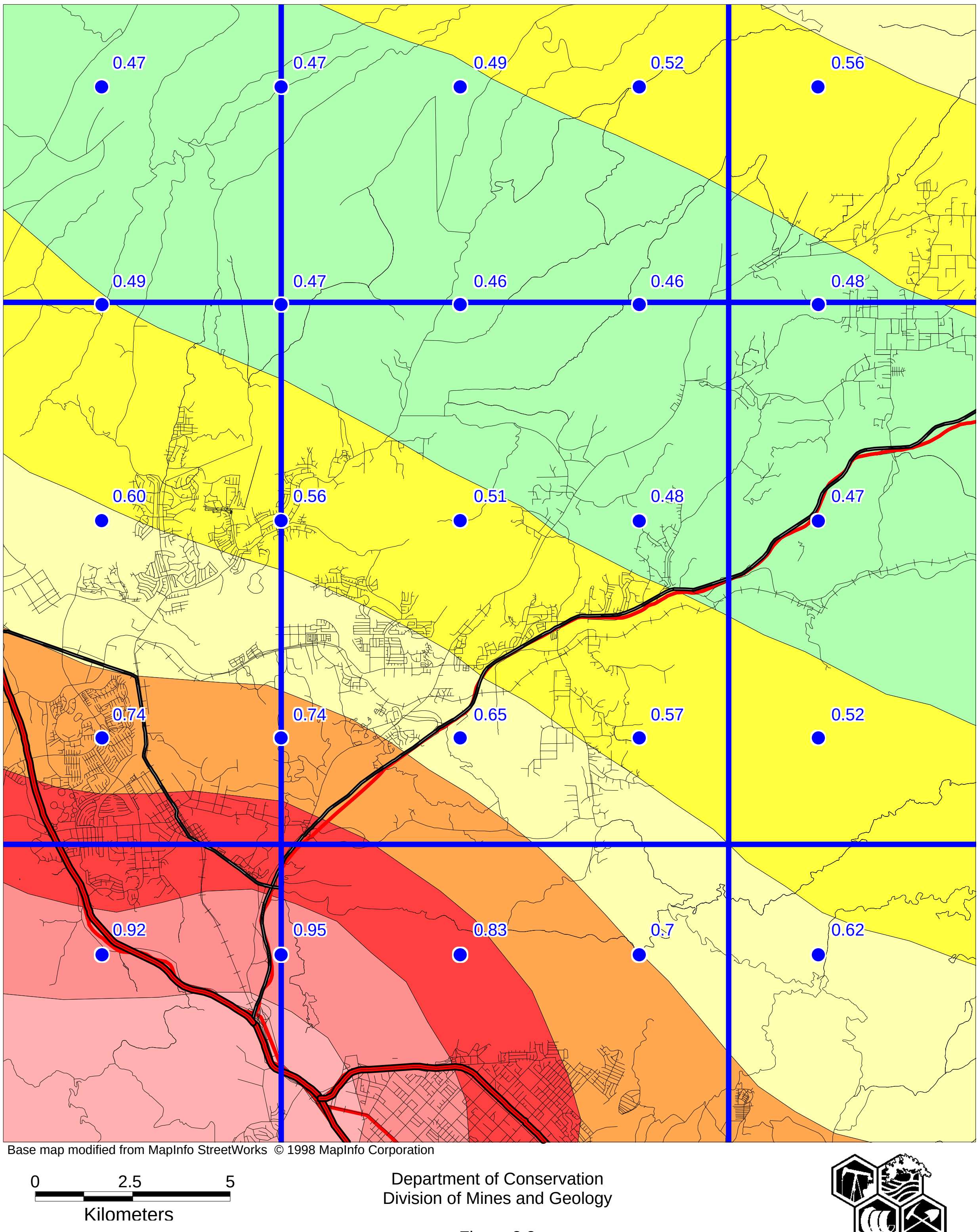
Figure 3.1

MINT CANYON 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

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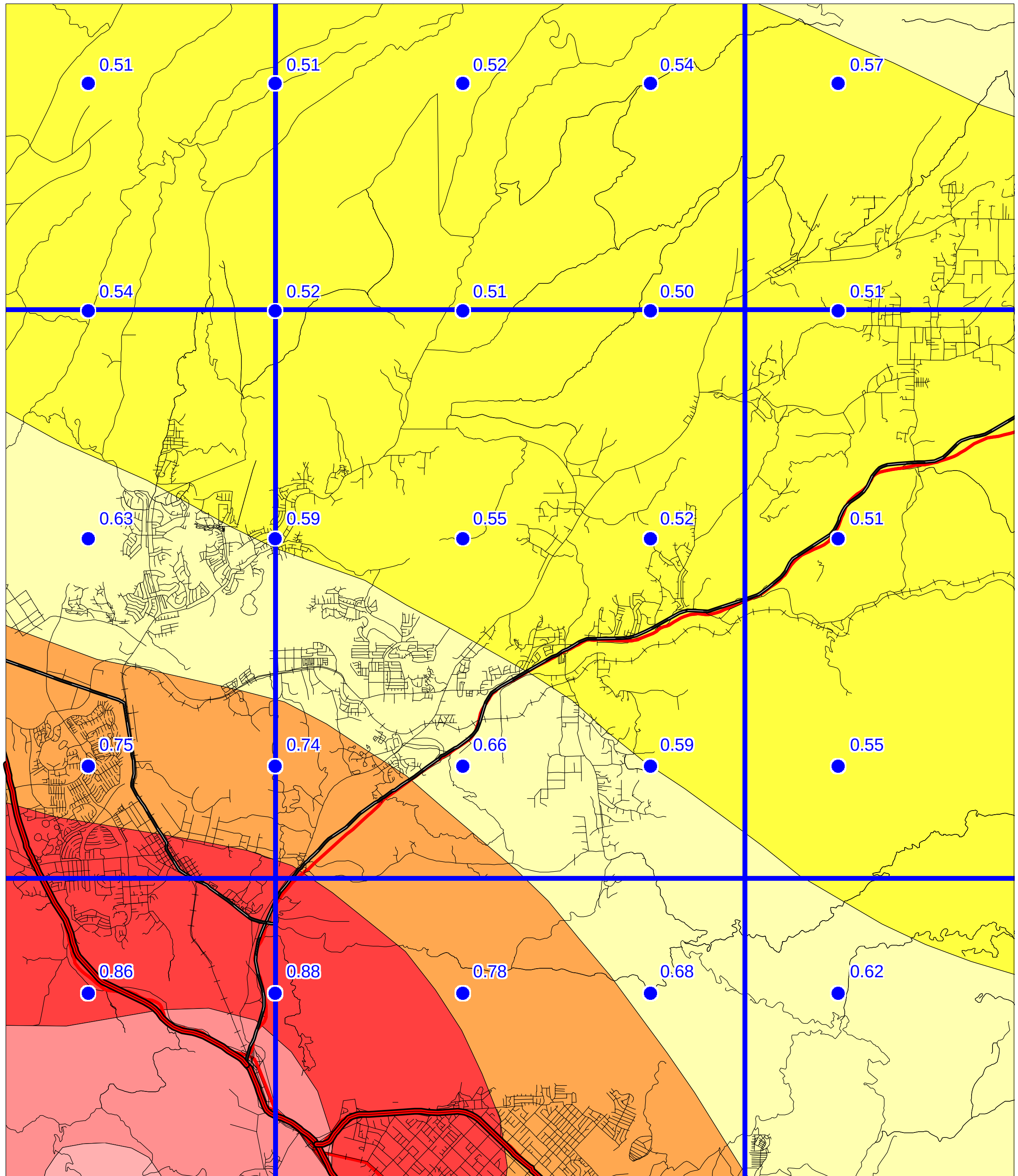
Figure 3.2

MINT CANYON 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

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Figure 3.3

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

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

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

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

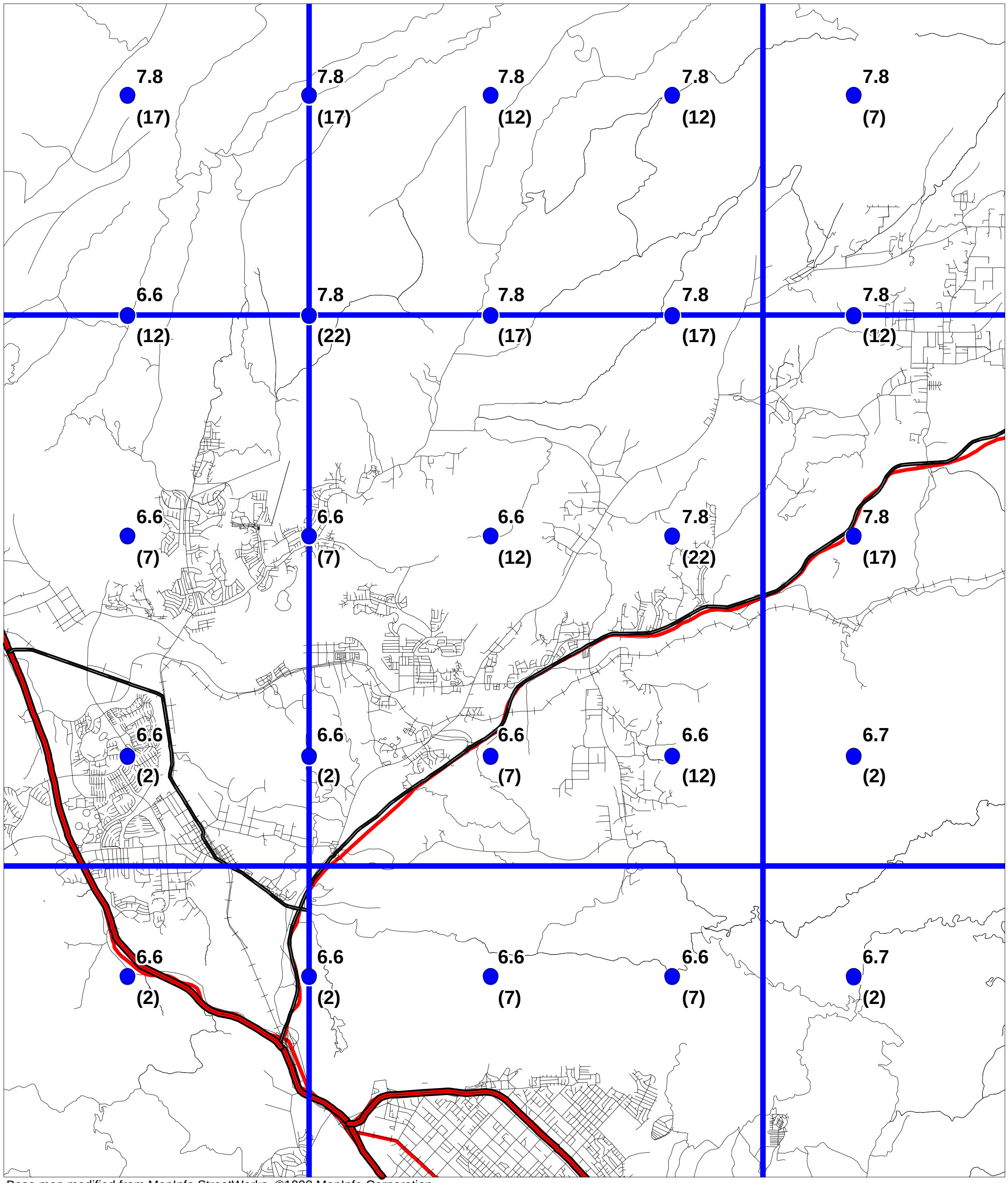
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss’ weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

MINT CANYON 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

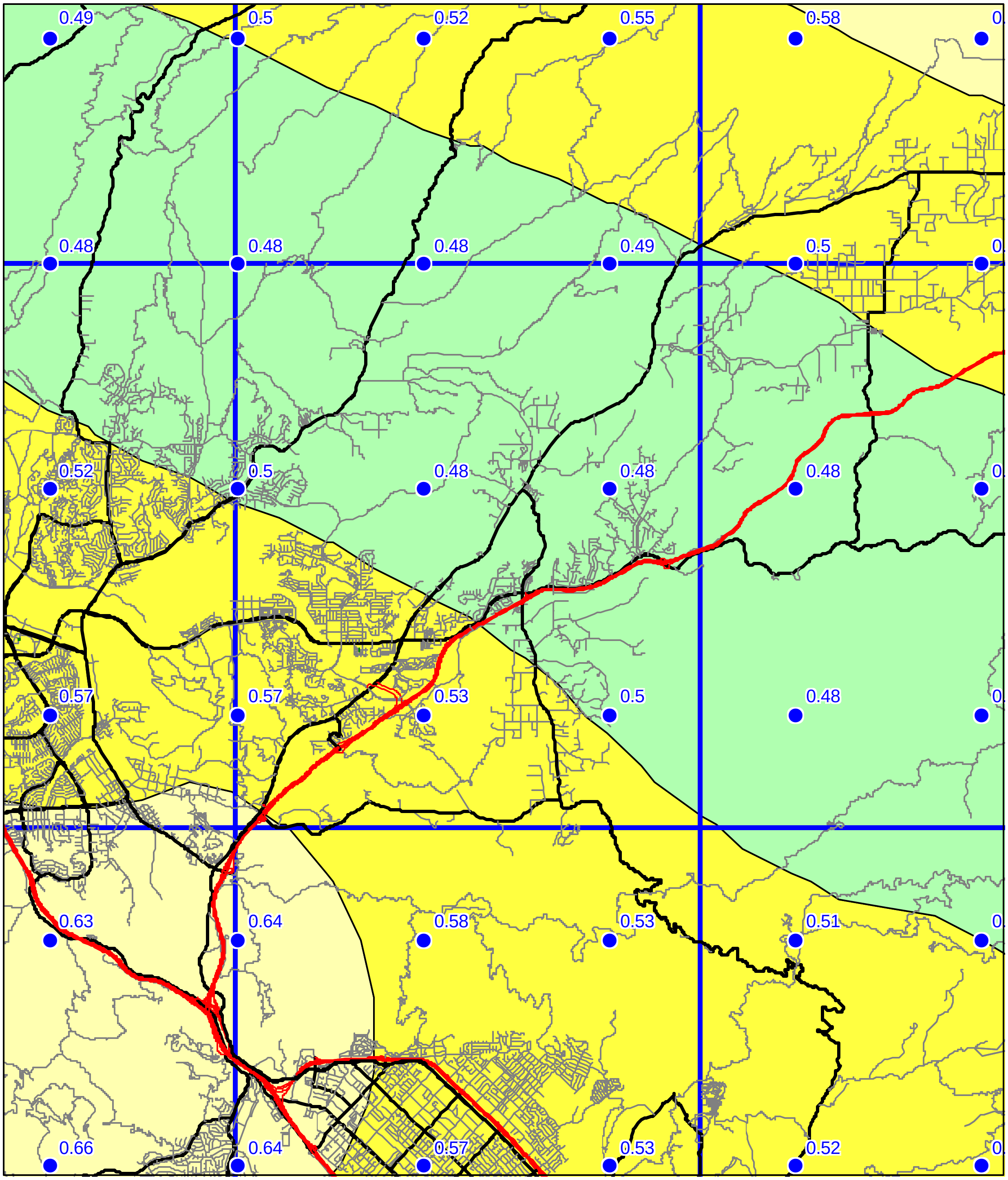
Figure 3.4

MINT CANYON 7.5-MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3

Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

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

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

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

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

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

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

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

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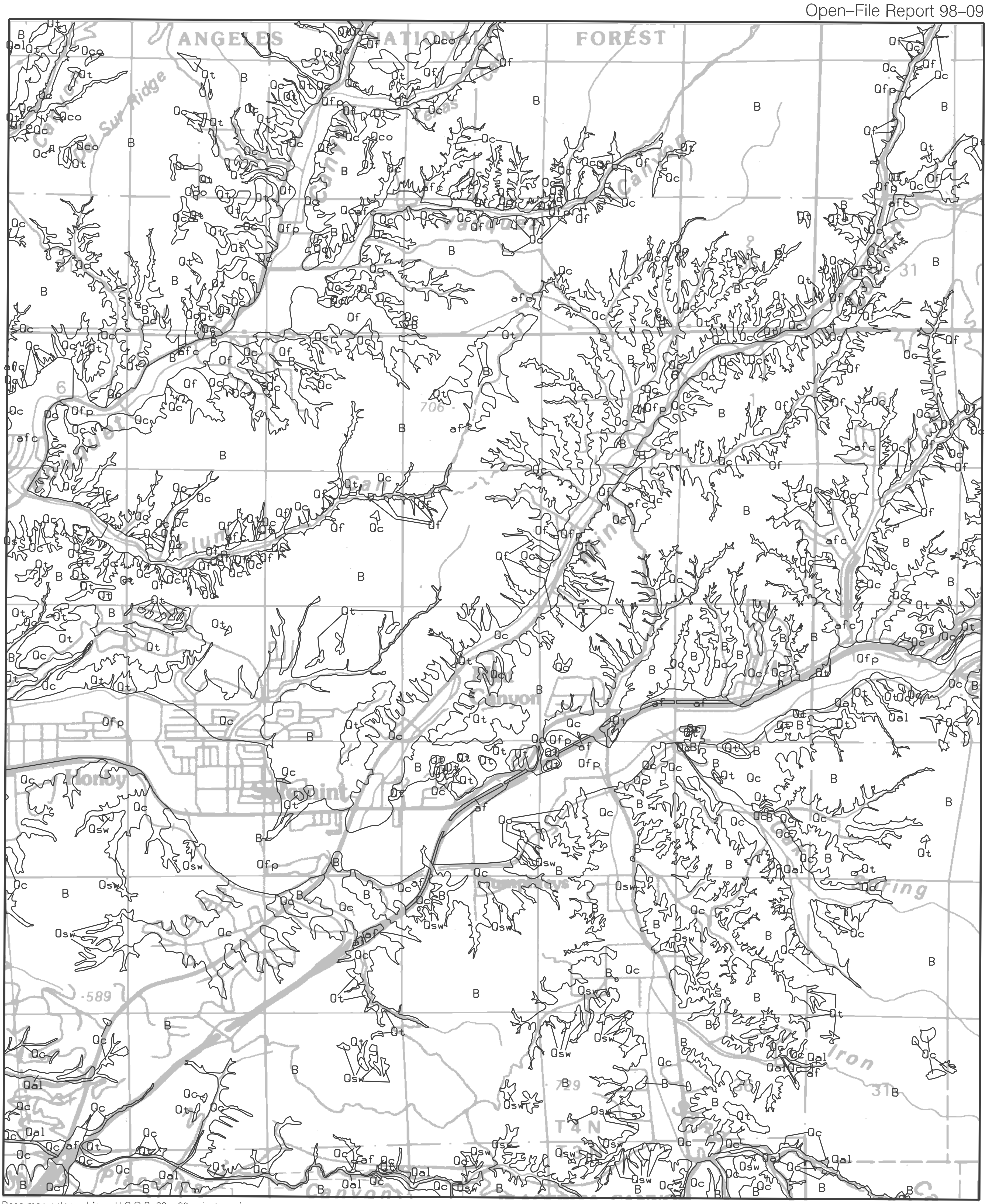

Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the Mint Canyon Quadrangle

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

B = Pre–Quaternary bedrock.

afc	Artificial Fill or Cut–Undifferentiated	Qf	Fan Deposits
af	Artificial Fill	Qfp	Flood Plain Deposits
Qal	Undifferentiated Alluvium	Qt	Terrace Deposits
Qc	Colluvium	Qco	Older Colluvium
Qsw	Slope Wash Deposits		

ONE MILE

SCALE

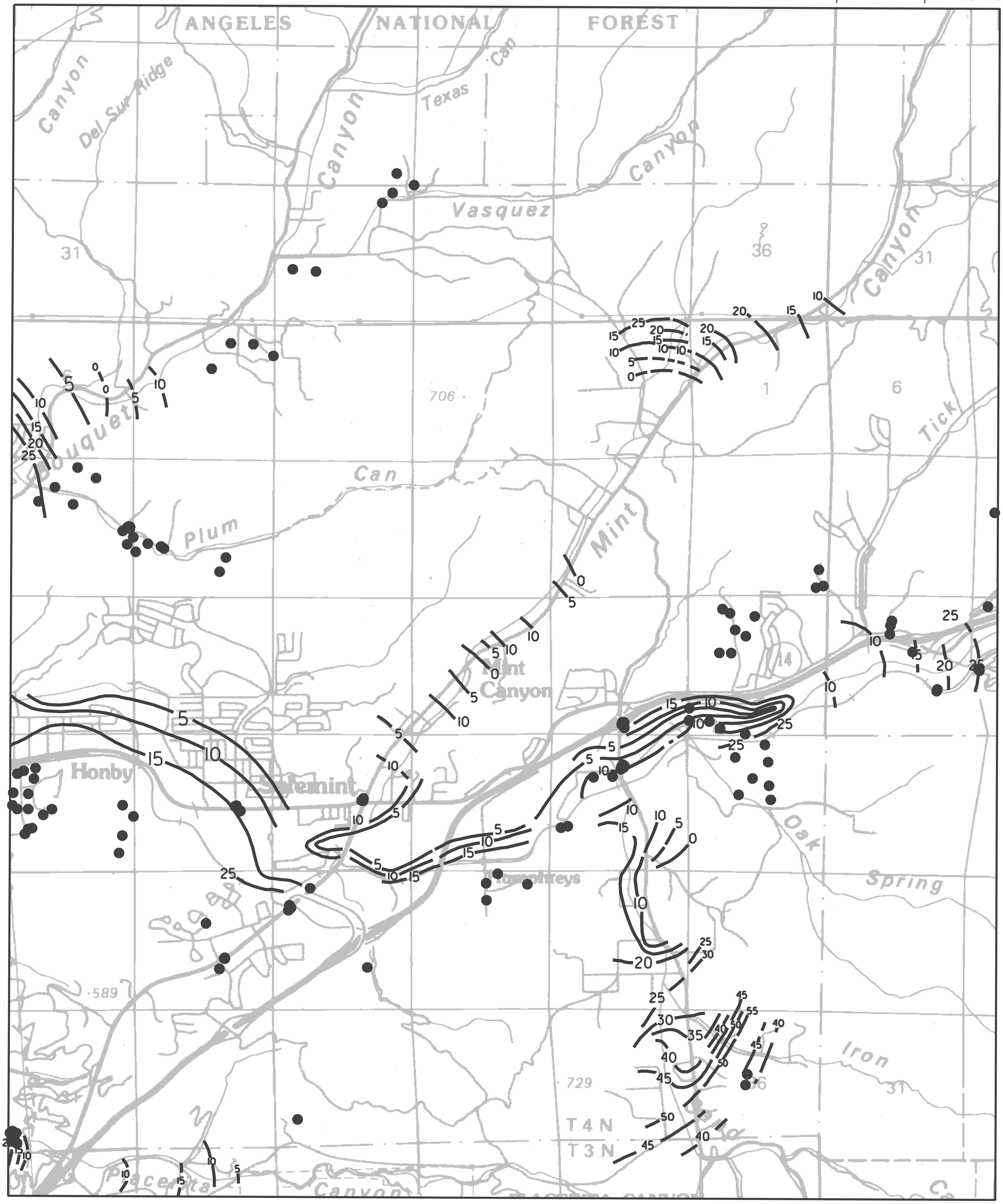

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Mint Canyon Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE

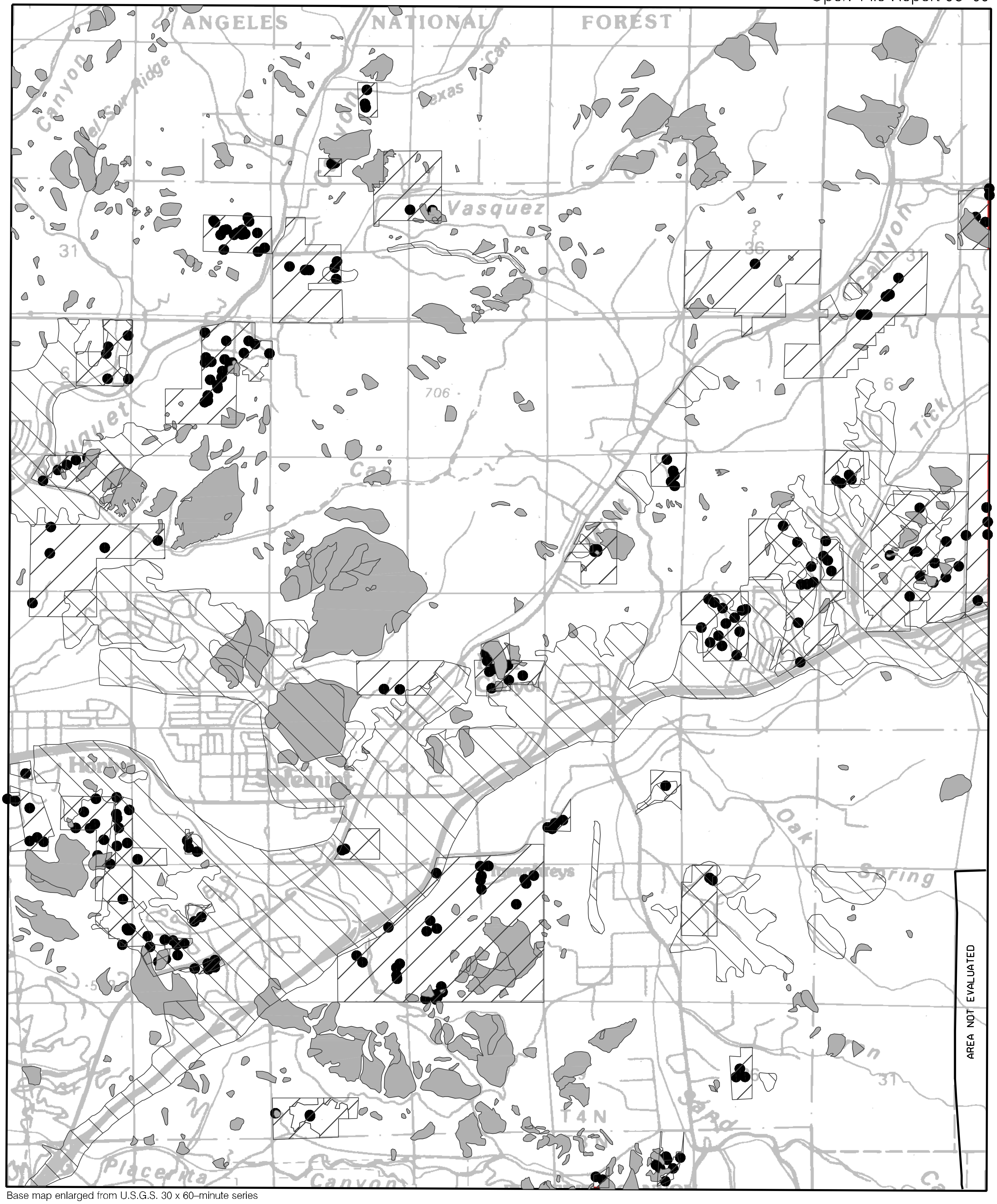

Plate 2.1 Landslide Inventory, Shear Test Sample Locations, and Areas of Significant Grading, Mint Canyon Quadrangle.

shear test sample location — landslide — area of significant grading — tract report with multiple shear tests

ONE MILE
SCALE